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POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

# JOURNAL DU CONSEIL

VOL. XVI · NO. 1

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
J. R. LUMBY

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
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AVRIL 1949

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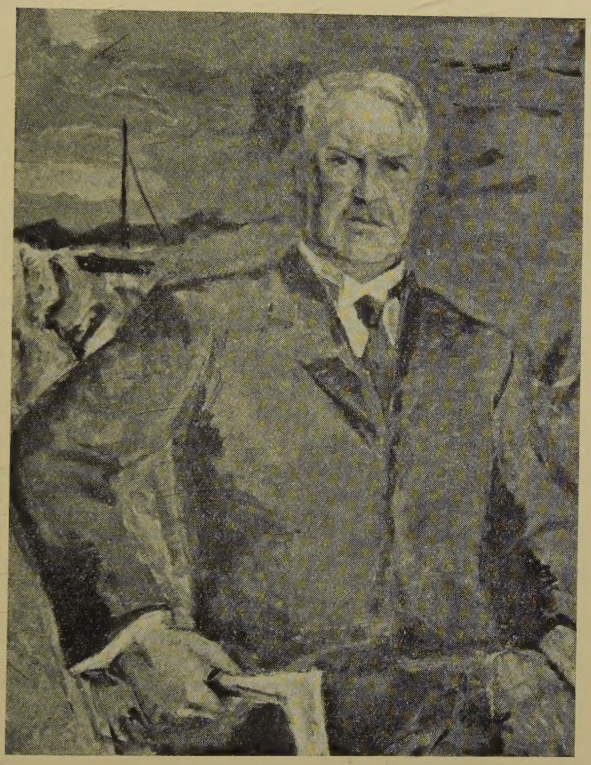


## Johan Hjort.

**1869—1948.**

JOHAN HJORT, late Professor at the University of Oslo, died on 7. October 1948, in Oslo.

He was born on 18. February 1869, and was the son of J. S. Aub. Hjort, Professor of Ophthalmology in the same University. As a young undergraduate he sought to follow in his father's footsteps and began by studying medicine at the University of Lund in Sweden. But he soon changed over to zoology, studying this subject under Richard Hertwig in Munich. At the Zoological Station in Naples he investigated the budding of Ascidians, publishing as early as 1893 a dissertation

on this, which attracted much attention. In his well known Textbook of Embryology, E. W. MacBride says that Hjort reviewed the whole subject in "a most masterly way".

When Johan Hjort subsequently returned to his native country, he became enthralled with the vast scientific problems underlying the fishing industry — which is of such paramount importance for Norway — and with his prodigious energy he came to devote himself to the development of the Norwegian fisheries. He soon succeeded in convincing the Government authorities of the value of scientific investigations to the fishing industry. He was the founder of Fiskeridirektoratet (the Board of Sea Fisheries) in Bergen. As Director of this institution he guided its activities for many years with outstanding success. He soon obtained a Government grant to build a research vessel, admirable for its time, which he named the "Michael Sars" after the famous Norwegian zoologist. Such a vessel was essential to his plans for exploration, and with the "Michael Sars" he undertook expeditions along the extensive Norwegian coast, and in the North Sea and the North Atlantic (Iceland, Spitsbergen). In the course of these voyages he investigated the more important species of fish and found new fishing grounds. Special mention should be made of his discovery of rich stocks of the deep-sea prawn, *Pandalus borealis* Kröyer, in the Norwegian fjords. A new fishery was thus created, which is still of great consequence for Norway.

As Fisheries Director he showed himself to be not only an excellent scientist but also an admirable administrator. With his burning enthusiasm and immense capacity for work he achieved magnificent results.

Hjort also knew how to collect about him a team of able collaborators. Of these may be mentioned Professors Fridtjof Nansen, Björn Helland-Hansen, H. H. Gran, D. Damas, Knut Dahl, and Johan T. Ruud, and Consultants Einar Lea, Oscar Sund, and Paul Bjerkan. He also began at an early stage to co-operate with the famous Danish biologist C. G. Johannes Petersen and the two well known Swedish hydrographers Gustaf Ekman and Otto Pettersson.

As a result of his practical scientific research, Hjort published in 1896 an important work entitled *Hydrographic-Biological Studies of the Norwegian Fisheries.* This was followed by his and his collaborators' *Report on Norwegian Fishery and Marine Investigations*, published in three large volumes in 1900 and 1909 (2 volumes).

At first he turned his attention primarily to ascertaining the life histories of the gadoids and the herring. He started large-scale marking of the cod, which is of such importance for Norway, and was thereby able to establish the fact that every year this fish undertakes long migrations — in the winter to the Lofoten spawning grounds, after spawning to the Norwegian Finmark coast and Barents Sea, and the following winter back to Lofoten.

H j o r t also put forward as a fundamental problem the investigation of the relation between the distribution of the different species of fish, with special reference to their spawning grounds, and the character of the environment. His collaborator D a m a s was given the task of studying the distribution of the various gadoids and their spawning grounds, and eventually published the famous treatise entitled *Contribution à la Biologie des Gadides*, which appeared in 1909. In this it was shown that the various gadoids had different regions of distribution and spawning grounds, delimited by the differing temperatures and salinities of the water.

The Norwegian herring fishery, so important for his country, was naturally also the object of J o h a n H j o r t's energetic investigations. Here it was chiefly the great fluctuations in the herring fishery that claimed his attention. It was in this that he became the real pioneer. By determining the age of the herring, he analysed samples of the herring catches and was able to demonstrate that the strength of the different year-classes varied in an unexpected manner. Thus he showed that in the Norwegian spring-spawning herring the 1904 year-class greatly predominated over the other year-classes. In 1910 it formed more than 77 % of the entire catch. It was also shown that the herring fishery increased enormously during 1909—1913, when the 1904 year-class was extremely prominent in the catches. These famous investigations of H j o r t's, which were reported in his publication of 1914 entitled *The Fluctuations of the Great Fisheries*, lifted fishery research to a higher plane, and immediately won him numerous followers from among his fellow scientists.

But H j o r t's interests extended far beyond the questions affecting local fisheries. He wanted his studies to embrace the great Atlantic, and the reaction of the animals to the environment was always his chief concern, for only in this way was it possible — so he maintained — to arrive at a fuller understanding of the world of Nature.

In 1910, with the support and patronage of Sir J o h n

Murray, Hjort started on his famous expedition to the North Atlantic with the "Michael Sars". The general results of this expedition were recounted in the famous book, *The Depths of the Ocean*, published in 1912. In this extremely interesting book he gives many examples of the interaction between the animals and their environment.

Johan Hjort realized at an early stage that international co-operation was essential for solving the scientific problems associated with the life history of fish. As early as the 1890's he began his co-operation with the Danish and Swedish scientists mentioned above. When the International Council for the Exploration of the Sea was established in 1902 he, like Otto Pettersson and Gustaf Ekman, was one of the prime movers. He represented Norway as delegate to the Council from that time until his death, that is, for 46 years. And it may be said without exaggeration that no one has made such an important contribution as he to the success of the work accomplished by the Council. Both as a scientist and as an administrator he was for long the leading force. After having been a Vice-President for many years, he was elected President in 1938. He was delighted by this honour and felt that he had been entrusted with the great task of keeping the international organization in being and unimpaired during the second World War; and in this he succeeded. He was President until his death.

During his many years of work in the service of the fisheries he never lost sight of the fact that the scientific investigation of the fisheries should aim primarily at benefiting the fishing industry and that the scientific findings should be given practical application. The fishermen should be given the opportunity of using the riches of the sea to the greatest advantage (the "optimum catch"). It therefore gave him great satisfaction to be able to take part in the Fishery Conferences held in London in 1936 and 1937 when, for the first time, an international agreement was entered into by a large number of European countries for the adoption of joint measures for the prevention of overfishing and for a better economic exploitation of the fish stocks. As President of the International Council for the Exploration of the Sea, he was also present at the Overfishing Conference held in London in 1946.

He always concerned himself greatly with the welfare of the fishermen and never missed an opportunity of drawing attention to it. When the International Council for the Exploration of the Sea celebrated its 25th Jubilee at the

Annual Congress in Stockholm in 1927, he rose at the grand banquet and spoke in honour of the fishermen. He reminded the guests that it was their duty to promote the welfare of the fishermen and they skould never forget those who by hard and dangerous work wrung a livelihood from the sea. The fishermen themselves appreciated this and it may be mentioned that, among the many marks of homage at H j o r t' s funeral, there came a mute expression of gratitude from the prawn fishermen of Oslo Fjord in the form of a beautiful wreath.

H j o r t was Fisheries Director in Bergen from 1900 until 1916. Then, in 1921, he became Professor of Marine Biology at the University of Oslo. During the period that followed, H j o r t became keenly interested in the other great Norwegian marine industry, namely, whaling. He was for a long time President of Hvalrådet (the Norwegian Whaling Council), planning and supervising investigations in the various fields of marine biology, especially those of importance to whaling. In this sphere, too, he knew how to find valuable collaborators, and numerous papers were published in the excellent series *Hvalrådets Skrifter.*

But H j o r t had many interests outside natural science; he had long occupied himself with philosophical problems, and social questions also appealed to his wide-encompassing mind. These last questions he always considered from a biological point of view. He enjoyed studying A r i s t o t l e and P l a t o as much as A d a m S m i t h and D a v i d H u m e. As he grew older, L a m a r c k, K a n t, and G o e t h e probably became his favourite authors. Newly published scientific literature of general interest he devoured with the greatest eagerness. On the other hand, he had no interest whatsoever in what is known as fiction.

As a more concrete result of his philosophical studies he published various books. In 1920 appeared *The Unity of Science* and in 1931 *The Emperor's New Clothes.* During the second World War he published *Kriget, det store Folkbedrag.*

Latterly he often lectured about his outlook on life and society, and his last published lecture, "The Renaissance of the Individual" (*Journal du Conseil*, 1948), may be regarded as his testament.

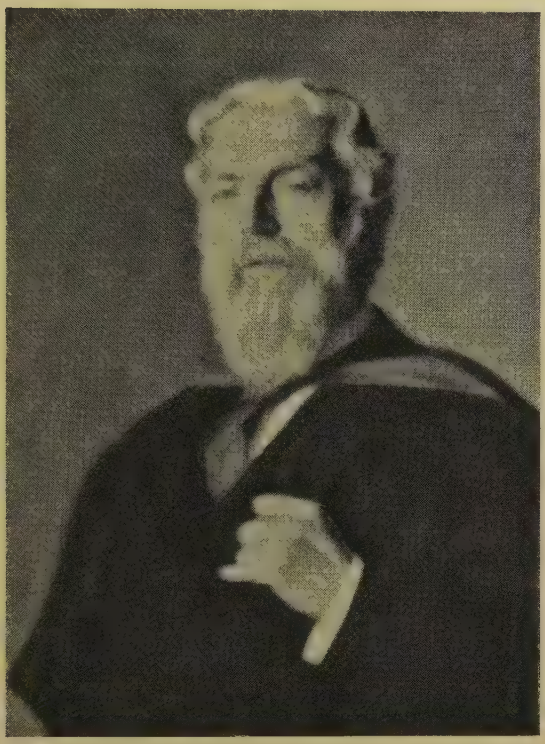
J o h a n H j o r t was a loyal patriot but also a great internationalist. International co-operation was one of the keynotes of his being and he liked to dream of the United States of Europe and even of the World.

The title of his testament makes it clear that Hjort was a decided individualist. He hated all the oppression and restrictions that now prevent the free development of the individual. He was himself an exceedingly independent man, who could never compromise with his convictions. He had many friends, but, of course, opponents also. When it was a case of upholding the right and the noble, he always remained steadfast. Then his vehement temperament soon showed itself. The most remarkable instance of this happened in 1916. At the instance of the Norwegian Government he had prepared a draft of a certain trade agreement with a representative of the British Government. When the Norwegian Government would not accept this draft, he took, what was for him personally, the serious step of tendering his resignation from his post as Fisheries Director, and the Government was not able to induce him to remain at that post. He could not go back on his word to Great Britain, a country for whose people and culture he felt the greatest sympathy and admiration.

Johan Hjort had a cheerful disposition though he grieved very much about the folly of the world. But when he heard one day, during a meeting at Copenhagen in June 1944, that British and American troops had invaded Normandy, then he rejoiced like a boy, and old as he was, he could not help singing "Le jour de gloire est arrivé".

Deep sorrow was felt when, during the last Annual Meeting of the Council for the Exploration of the Sea in October 1948, the news was received that Johan Hjort had passed away. The Council will long remember with gratitude his eminent personality.

*K. A. Andersson.*



## D'Arcy Wentworth Thompson.

**1860—1948.**

THE life and the achievements of Professor Sir D'Arcy Wentworth Thompson contradict the oft-repeated fallacy that none but the narrow specialist can, in these days, add worthily to the sum of knowledge. Naturalist by profession, though with more than a smattering of cognate sciences, humanist almost by inheritance, his life held a multiplicity of interests from which he extracted full measure, and his accomplishment has placed in his debt the classical scholar, as well as the general biologist and, along more special lines, the student of our great fisheries.

It cannot be doubted that D'Arcy Thompson was fortunate in his parents and fortunate in his formal education; for to the influence of his father in particular, of his schools and schoolmates, and of his Universities can be traced the special interests and the wide sympathies which marked his later life. His father, also D'Arcy Wentworth, was classical master at Edinburgh Academy before becoming Professor of Greek at University College, Galway, and the son, after a few years of preparatory schooling, in which nature study rambles were a special and at that date an unusual feature, proceeded to Edinburgh Academy where he came under the influence of Dr. Clyde, a teacher who contrived to impart an extraordinary amount of general information. The quality of the teaching and the calibre of his schoolmates may be judged by the record of his class, for of their small number, one was awarded the Victoria Cross, one became a Cabinet Minister of State and a Peer, four were elected fellows of the Royal Society of London, and one was a Royal Academician.

At the age of 17 D'Arcy Thompson matriculated in medicine at Edinburgh University. Here he came under the spell of Professor Sir Wyville Thomson who had just returned from leading the famous "Challenger" Expedition, and so was introduced to the exploration of the seas and the new science of Oceanography. Two years later, he proceeded to Trinity College, Cambridge, with a classical scholarship, but science was obviously his bent and he read Zoology with Balfour and demonstrated in Physiology under Foster.

It was not long before his qualities as an expositor were recognized. When a University College was founded in Dundee in 1880, he was selected from many candidates of merit (including Patrick Geddes, J. T. Cunningham, and W. E. Hoyle) as its first Professor of Biology. This was in 1884, when he was 24 years of age; in 1888, he became Professor of Natural History when Professor (later Sir) Patrick Geddes was appointed to the new Chair of Botany; and in 1889 University College was affiliated to the University of St. Andrews. The connexion was to be a life-long one, for in 1917 he followed W. C. McIntosh (also a leading fishery expert) as Professor of Natural History in the mother University of St. Andrews, and he died in office in 1948, having virtually served this oldest of the Scottish pre-Reformation foundations, as Professor, for an unbroken period of over 64 years. As a teacher, he was superb. His command of language, his skill in drawing on the blackboard, the range

of his knowledge, his sense of style and his resonant and beautifully modulated voice, made his lectures works of art. He was fond of teaching and even in his last illness he was accustomed to gather his honours students round him at his bedside.

It is traditional that University Professors should perform many public services outside the University, and in such activities D'Arcy Thompson played a full part. In 1896—7 he was appointed a delegate to the Behring Sea Conference at Washington, for the Protection of Fur Seals, and his services were rewarded in the following year with a C.B. In 1898 he became the scientific member of the Fishery Board for Scotland, and continued in this capacity until the Board was merged in the Scottish Home Department in 1939. In 1899 he was one of the British delegates at Stockholm to consider the question of the foundation of an International Council for the Exploration of the Sea, and again in 1901 at Christiania. When, in 1902, the International Council was constituted with its headquarters at Copenhagen, he was appointed one of the two British delegates, a post which he continued to hold off and on till 1948. He was Editor of Statistics (*Bulletin Statistique*) and Chairman of the Statistical Committee from 1920 to 1947. His publications in the international series deal principally with statistics of the trawl fisheries. In the Jubilee Volume of the International Council, tribute is paid to his influence during the Council's infancy and to the long and honourable part which he played in its work.

D'Arcy Thompson happily combined the detailed knowledge of the zoologist and the enthusiasm of the naturalist with a love of classical lore, and so, apart from his specialized zoological studies (which ranged from Hydrozoa to fisheries and whaling) his earliest volume was a *Glossary of Greek Birds* (1895), followed in 1910 by his translation of and commentary on Aristotle's *Historia Animalium*, and in 1945 ( at the age of 85) by a *Glossary of Greek Fishes*. His outstanding contribution to scientific thought and knowledge was, however, of a different kind, where he integrated his knowledge of physics and mathematics with zoology in his classic interpretation of the physical aspects of biological phenomena — *On Growth and Form* (1917). A second edition, greatly enlarged, appeared in 1942, both editions, therefore, being the result of special research during war-time. As he himself says, "my sole purpose is to correlate with mathematical statement and physical law, certain of the simpler outward phenomena of organic growth and

structure, *ex hypothesi,* as a material and mechanical configuration". But he adds the warning, "one does not come by studying living things for a lifetime to suppose that physics and chemistry can account for them all." As stated elsewhere[1]) "the central theme is the enquiry as to how far the form and structure of living things can be interpreted in terms of the physical forces acting within the lifetime of the individual organism." It can be said that this great work, a veritable mine of information, has given a new stimulus to the investigation of animal form in this and other countries.

In the course of his long life, many honours and tributes to his worth came to this St. Andrews Professor with an international reputation. In Queen Victoria's reign, he was made a Companion of the Bath (1898); King George V. created him a Knight (1937); learned Societies and Universities acclaimed him (Oxford with a D. C. L.) — the catholicity of his interests is shown by his Presidentship at diverse times of the Royal Society of Edinburgh, the older Royal Physical Society, of the Royal Scottish Geographical Society of the Classical Association, and the Scottish Classical Society, and of the Edinburgh Mathematical Society. He was Linnean medallist in 1938, and Darwin medallist of the Royal Society of London in 1948; he was LL. D. of the Universities of Aberdeen and Edinburgh, D. Sc. of Dublin, and by invitation delivered special lectures at Oxford, Birmingham, Harvard, and elsewhere. Finally, as a tribute to his influence and scientific eminence, there was dedicated to him, to his great pleasure, a volume of *Essays on Growth and Form* under the editorship of Professors W. le Gros Clark and P. D. Medawar.

In appearance Sir D'Arcy Thompson was most unconventional. His flowing beard, his massive and magnificently shaped head, his erect and proud bearing, made him a striking personality and a conspicuous figure anywhere. His friendship with young people was particular and charming. As he himself has said, he was negligent of sport, but living as he did in the home of golf, it is interesting to record that he played the game occasionally in his younger and not so young days and that he was a member of the famous Royal and Ancient Club of St. Andrews.

The writer of the Obituary Notice[2]) in the Edinburgh Academy Chronicle has stated that he wrote with affection and

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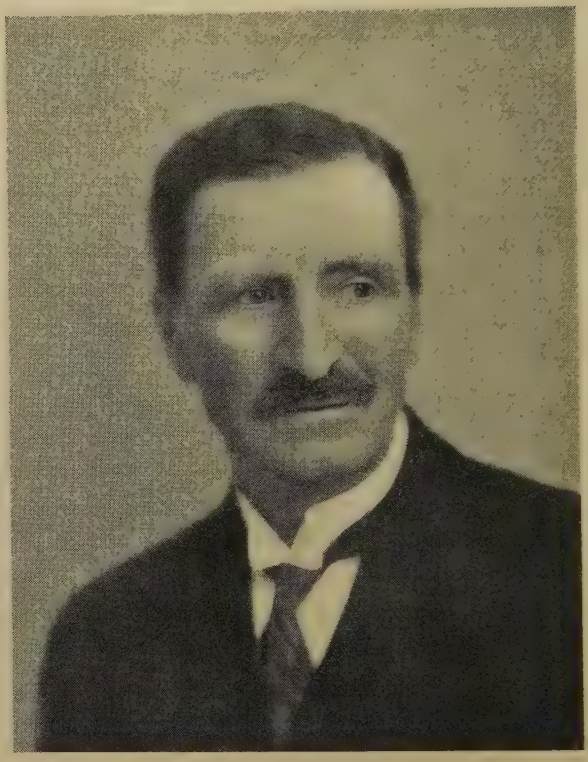
[1]) Calman, W. T. Nature, Vol. 162, No. 4107.
[2]) Edinburgh Academy Chronicle. Vol. LV, No. 3. Oct. 1948.

reverence for a great Academical, so the present writer feels it no lees an honour to record herein a deep sense of gratitude for the unfailing courtesy, friendly help, and able guidance, readily shown him for over a quarter of a century, in the affairs of the International Council for the Exploration of the Sea and in the service of the Fishery Board for Scotland.

Professor Sir D'Arcy Thompson flew to India in 1946 to attend a Science Conference at Delhi as a representative of the Royal Society of London, but became indisposed during the meetings and was invalided home. On his return, he survived an acute attack of pneumonia, but his strength was undermined and he passed away peacefully at his home in St. Andrews on 21. June 1948, at the advanced age of eighty-eight. So has passed a conspicuous and great figure in British academic and scientific life.

As this notice was on the point of completion, news arrived (from Professor James Ritchie, whom I have had the advantage of consulting throughout) that Sir D'Arcy's widow, Lady Thompson, died at St. Andrews on 6. February, after a long period of ill-health. She was a person of great charm and made her own distinctive contribution to a gracious partnership which lasted for 47 years. She is survived by three daughters who as musician, teacher, and artist, continue the cultural tradition of their family.

*R. S. Clark.*



## Ove Paulsen.

**1874—1947.**

THE botanist Ove Paulsen died on 29. April 1947. Paulsen was one of those many marine scientists associated with the International Council from its very start.

Marine biology represented only one side of Ove Paulsen's activities; he carried out important work in other fields as well. His thesis for the doctor's degree dealt, for example, with the vegetation of the Transcaspian lowlands, investigations resulting from an expedition to Transcaspia, Pamir, and Persia in 1898 to 1899 in which he took part as a botanist. From 1900 to 1920 he held a position in Copenhagen at the University

Museum of Botany, and from 1920 to 1944 he was a professor of botany at The Royal Danish School of Pharmacy. His activity there was one of outstanding significance, especially as an author of text-books.

But here we will primarily remember him as a marine investigator. When the Danish Commission for the Exploration of the Sea was started in 1902 he was appointed an assistant at the Plankton Laboratory where he continued to work until 1916. From 1931 to 1946 he was chief of this laboratory.

As a marine biologist Ove Paulsen is known chiefly for his work on the peridineans. At the beginning of this century our knowledge of the systematics of this group was only small. Paulsen contributed a very great deal to the classification of their species, principally those of the North Atlantic. He had a sharp eye for systematic valuation which, added to his thoroughness and critical judgement, made his work outstanding. He was, however, not only a systematist, but was also very keenly interested in the biology of species and their distribution; investigations into the general biology of plankton, especially phytoplankton, constituted a great part of his work.

In the large handbook edited by Brandt and Apstein, *Nordisches Plankton*, Ove Paulsen dealt with the Peridinea. But he also worked on zooplankton, and his prominent paper on the important copepod *Calanus finmarchicus* in Icelandic waters may be mentioned.

In later years he published only minor papers on plankton of a more popular nature, except for a report on microplankton in the Mediterranean, written in Malaga in 1929, when he was an instructor in marine investigations in Spain.

At his death he left a manucript, almost ready for the press, on the North Atlantic Dinoflagellates, the result of many years' investigations, which Julius Grøntved is preparing for publication.

Ove Paulsen was unpretentious and never eager to make himself conspicuous; nevertheless he enjoyed a great reputation in international circles as a man of the world and a great linguist. Either at work or on holiday he was an ever charming companion. He was a distinctive character, well-balanced and chivalrous. All marine workers will feel his loss deeply.

His publications are listed in Carl Christensen, "Den Danske Botaniske Litteratur 1880—1911", København, 1913, and "Den Danske Botaniske Litteratur 1912—1939", København, 1940.

*E. Steemann Nielsen.*

# Editorial Notes.

We are pleased to record that the Zoological Society of London has awarded its Gold Medal to Mr. H. G. Maurice, Président d'Honneur of the International Council for the Exploration of the Sea. This is a particularly notable honour, since this is the fourth occasion only on which the Society's Gold Medal has been awarded.

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The International Council for the Exploration of the Sea, following a recommendation from the Plankton Committee at the meeting held in Berlin on 16th May 1939, has decided to publish illustrated sheets of the zooplankton of the north-western Atlantic, under the editorial direction of Dr. P. Jespersen and Mr. F. S. Russell.

These sheets are not intended to be short cuts to identification, but they are to prevent unnecessary waste of time and possible introduction of errors of identification by plankton workers who cannot be specialists in every animal group. The valuable *Nordisches Plankton* is now out of date for many groups, and it is difficult for a worker to make sure that all the latest literature on each group has been seen. Accordingly these sheets can be regarded as up-to-date guides on the present position in each group with references to the best literature on identification. Since they are issued in loose-leaf form it is hoped that it may be possible to issue amendment sheets to keep them up to date.

The sheets will appear as and when the authors are able to produce them and they will, therefore, not be in any systematic order. They will, however, be numbered consecutively so that workers can ensure that they have their sets complete, and they can then be arranged to suit the workers' own wishes.

# Some Characteristic Features in the Variation of Surface Temperature in the North Atlantic.

By

† J. P. Jacobsen.

## Preface.

AT the time of his death in June 1946 Dr. J a c o b s e n, Hydrographer to the Council, had in hand work on the variation of surface temperature in the North Atlantic. Though the work was not quite completed, it was considered that even in this incomplete state the paper contained so much of interest that it ought to be published. At its Meeting in 1947 the Hydrographical Committee recommended that the paper should be printed in the publications of the Council (see Rapp. & Proc.-Verb., Vol. CXXI, 1ère partie, p. 39).

Elaboration of methods takes up a considerable part of the paper, and its main purpose was evidently to give methods that might be of value for the working-up of comparable material in the future. As to the hydrographical results of the work attention should be drawn particularly to Table 3. This table gives for each of the localities considered correlation-coefficients between the surface temperature for one month and the surface temperature one, two, etc., to six or nine months later. From this table it appears that the decrease of the correlation-coefficient $r_{pq}$ with increasing values of the difference q—p months varies from one locality to another. This decrease may be approximately expressed in various ways, and Dr. J a c o b s e n has chosen the expression

$$r_{pq} = r^{[(q-p)^E]}$$

As seen from Figure 6 it is possible with this formula — by choosing suitable values of E — to obtain a fairly good approximation to the actual variation of $r_{pq}$ with q—p and thus to characterize this variation by the quantity E. The value of E is a measure of the rate at which a temperature anomaly vanishes. As appears from Figure 5 E varies fairly regularly with locality. Thus, E has high values for the areas influenced by the polar front (10 and 11). For the areas to the south and southwest of Iceland (12, 13, 14, and 15) E has considerably lower values. As emphasized by Dr. J a c o b s e n, this may be explained by the fact that in the latter areas the temperature anomalies of the Atlantic Current play a prominent part: as these anomalies are of long duration they give low values of E. For the Faroe Islands (Station 18) also we find a

rather low value of E. However, high values of E are found for an area north of Scotland (16), for the stations off the Norwegian coast (19, 20, 21), and for a station in the easternmost part of the North Sea (22).

At the request of Prof. Martin Knudsen I have gone over the manuscript and prepared it for publication. Only minor alterations and additions have been undertaken.

*Jens Smed.*

## 1. Introduction.

On the suggestion of Professor Otto Pettersson the Bureau in the years 1915—1918 put in hand the working up of data on surface temperature in the North Atlantic for the years 1900—1913. The results are published in the Bulletin Hydrographique 1919. These data relate to selected areas or stations. For each area or station the mean value t of the surface temperature is computed for each month in the years considered, namely 1900—1913. The general monthly means $\vartheta$ and the anomalies $t-\vartheta$ are also computed. The values of t, $\vartheta$, and $t-\vartheta$ are given in tables, and $t-\vartheta$ in graphs also.

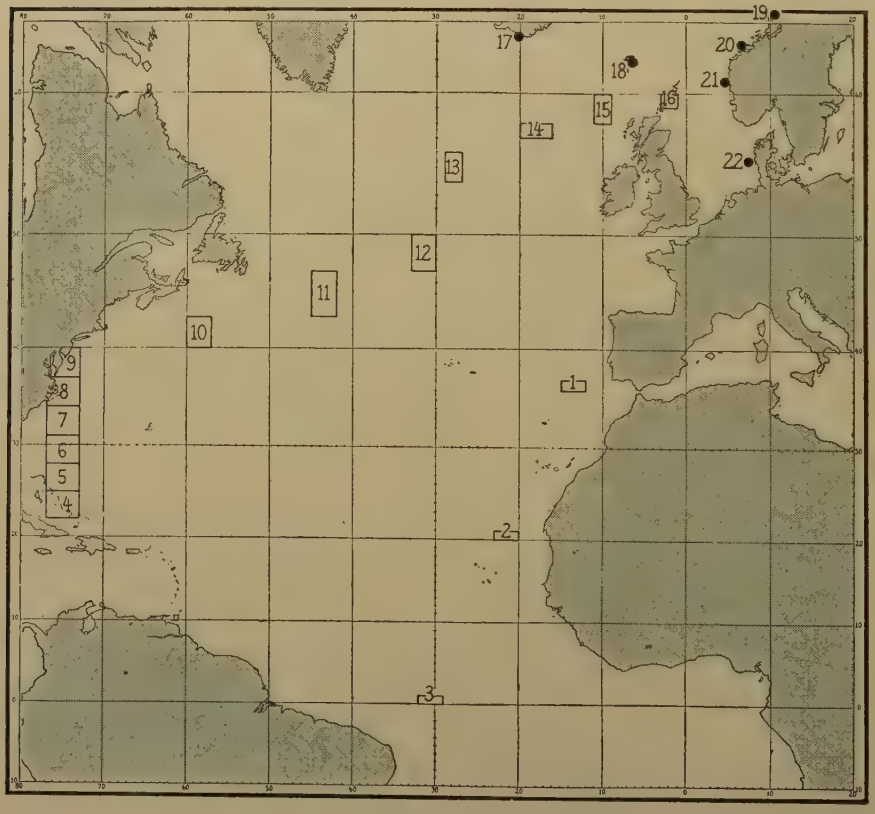


Fig. 1. Location of areas and stations.

In accordance with the plan for this work the actual results from the material considered were given in a comprehensive and easily accessible form. A discussion of the variations of the temperature with time and space has, however, never been taken up and at the request of Professor Martin Knudsen I have tried to investigate this problem more closely.

This investigation in the first place aims at an examination of the regularities in the variation of the temperature for each of the areas or stations. The main problem is, however, a discussion of the anomalies occurring in the temperature. At some places an anomaly may be maintained for several months, whereas at other places it may vanish in a short time. In order to characterize the different behaviours of the anomalies I have introduced a quantity E that may be termed the "effacement" constant. For areas in which the meteorological and hydrographical conditions are more or less alike the "effacement" constants may be expected to be similar also. Thus it should be possible to localize such areas geographically according to the effacement constant. This is in fact found to be the case to some extent. The present paper, however, may be considered only as an attempt at the solution of the problems connected with the temperaure anomalies occurring in the North Atlantic. Should it be found worth while, the far larger collection of temperature data from the North Atlantic could perhaps be treated on similar lines as the material here dealt with. Furthermore, a comparison of the "effacement" of anomalies of both temperature and salinity might perhaps make it possible to distinguish between the various influences on the water temperature at a given locality of the currents, the atmosphere, and the solar radiation.

In the present investigation it was necessary to have at disposal all — or nearly all — the monthly temperature means for the period 1900—1913 for each area. For this reason, only the areas and stations indicated in Figure 1 and numbered 1—22 are taken into consideration. The positions of these areas and stations are given in Table 1.

**Table 1.**

| No. | Lat. N. | Long. W. | Nationality | No. | Lat. N. | Long. | Nationality |
|---|---|---|---|---|---|---|---|
| 1 | 36°—37° | 12°—15° | German | 15 | 58°—60° | 9°—11°W. | Danish |
| 2 | 20°—21° | 20°—23° | „ | 16 | 59°—60° | 1°— 3°W. | „ |
| 3 | 0°— 1° | 29°—32° | „ | 17 | 63°26′ | 20°15′W. | Icelandic (Vestmanø) |
| 4 | 22°—25° | 73°—77° | Dutch | | | | |
| 5 | 25°—28° | 73°—77° | „ | 18 | 62°02′ | 6°45′W. | Danish (Thorshavn) |
| 6 | 28°—31° | 73°—77° | „ | | | | |
| 7 | 31°—34° | 73°—77° | „ | 19 | 64°48′ | 10°33′E. | Norwegian (Nordøerne) |
| 8 | 34°—37° | 73°—77° | „ | | | | |
| 9 | 37°—40° | 73°—77° | „ | 20 | 62°52′ | 6°33′E. | Norwegian (Ona) |
| 10 | 40°—43° | 57°—60° | „ | | | | |
| 11 | 43°—47° | 42°—45° | „ | 21 | 60°45′ | 4°43′E. | Norwegian (Hellisø) |
| 12 | 47°—50° | 30°—33° | „ | | | | |
| 13 | 54°—56° | 27°—29° | Danish | 22 | 55°34·1′ | 7°19·5′E. | Danish (Horns Rev) |
| 14 | 57°—58° | 16°—20° | „ | | | | |

**Table 2.**

**Constants relating to Temperature Variation at the**

| Locality | Annual mean $m$ °C | Annual period $R_1 \cos \frac{2\pi}{12}(q-q_1)$ Ampl. $R_1$ °C | Date of occurrence of maximum | Semi-annual period $R_2 \cos \frac{2\pi}{6}(q-q_2)$ Ampl. $R_2$ °C | Dates of occurrence of maxima | | A | B |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 17·6 | 3·2 | IX 3 | 0·4 | II 27 | VIII 28 | 0·3 | 0·1 |
| 2 | 21·7 | 2·4 | IX 19 | 0·5 | IV 6 | X 6 | 0·4 | 0·1 |
| 3 | 26·2 | 0·8 | III 24 | 0·3 | V 9 | XI 7 | 0·2 | 0·0 |
| 4 | 25·6 | 2·2 | VIII 22 | 0·1 | II 4 | VIII 6 | 0·1 | 0·1 |
| 5 | 25·1 | 2·8 | VIII 21 | 0·2 | II 8 | VIII 10 | 0·2 | 0·1 |
| 6 | 23·9 | 3·5 | VIII 18 | 0·5 | II 12 | VIII 14 | 0·4 | 0·1 |
| 7 | 23·1 | 3·8 | VIII 15 | 0·4 | II 3 | VIII 5 | 0·3 | 0·1 |
| 8 | 21·4 | 4·6 | VIII 12 | 0·3 | II 2 | VIII 4 | 0·4 | 0·3 |
| 9 | 14·6 | 8·2 | VIII 16 | 0·9 | II 5 | VIII 7 | 0·7 | 0·3 |
| 10 | 16·2 | 5·1 | VIII 4 | 0·6 | II 14 | VIII 16 | 0·7 | 0·5 |
| 11 | 13·2 | 4·1 | VII 3 | 1·3 | II 18 | VIII 20 | 1·2 | 0·7 |
| 12 | 13·4 | 2·3 | VIII 9 | 0·6 | II 12 | VIII 14 | 0·4 | 0·2 |
| 13 | 9·7 | 2·5 | VIII 16 | 0·4 | II 13 | VIII 15 | 0·3 | 0·1 |
| 14 | 10·2 | 2·2 | VIII 15 | 0·5 | II 10 | VIII 12 | 0·4 | 0·1 |
| 15 | 9·9 | 2·2 | VIII 17 | 0·5 | II 8 | VIII 10 | 0·4 | 0·1 |
| 16 | 8·9 | 2·7 | IX 1 | 0·3 | II 5 | VIII 7 | 0·2 | 0·1 |
| 17 | 7·2 | 3·2 | VII 29 | 0·6 | I 25 | VII 27 | 0·4 | 0·1 |
| 18 | 7·7 | 2·5 | VIII 18 | 0·2 | II 8 | VIII 10 | 0·1 | 0·1 |
| 19 | 7·2 | 4·3 | VIII 20 | 0·8 | I 28 | VII 30 | 0·6 | 0·2 |
| 20 | 8·2 | 4·0 | VIII 24 | 0·4 | I 30 | VIII 1 | 0·3 | 0·1 |
| 21 | 8·4 | 4·3 | VIII 28 | 0·5 | I 28 | VII 30 | 0·4 | 0·2 |
| 22 | 9·1 | 6·6 | VIII 22 | 0·4 | I 9 | VII 10 | 0·3 | 0·1 |

## 2. Regular Variations of the Surface Temperature.

The values given in Table 2 have been found from the grand monthly means, $\vartheta$, and the monthly means, t. Each line in the table contains the values referring to the locality indicated by its number in the first column of the table. The annual mean, $m$, is recorded in Column 2. By harmonic analysis the constants $R_1$, $q_1$, $R_2$ and $q_2$ were obtained in the expression $\vartheta = m + R_1 \cos \frac{2\pi}{12}(q-q_1) + R_2 \cos \frac{2\pi}{6}(q-q_2)$ for the temperature $\vartheta$ at the time q months after the beginning of the year. The amplitude, $R_1$, of the annual period is recorded in Column 3, and the amplitude, $R_2$, of the semi-annual period in Column 5. Instead of the displacement constants $q_1$ and $q_2$, in Table 2, Columns 4, 6, and 7, the times have been recorded for the maxima of the terms with annual and semi-annual periods respectively.

It is seen from the table that the values of $R_1$ and $R_2$ are extraordinarily large for areas 9, 10, and 11. These areas are situated on the

**Localities 1—22 (see Figure 1) in the North Atlantic.**

$$\left[\frac{1}{14}\Sigma\,(t-\vartheta)^2\right]^{1/2}$$

| Locality | J 10 | F 11 | M 12 | A 13 | M 14 | J 15 | J 16 | A 17 | S 18 | O 19 | N 20 | D 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0·5 | 0·4 | 0·4 | 0·5 | 0·5 | 0·5 | 0·6 | 0·4 | 0·4 | 0·5 | 0·6 | 0·4 |
| 2 | 0·6 | 0·7 | 0·8 | 0·9 | 0·6 | 0·6 | 0·6 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 |
| 3 | 0·2 | 0·3 | 0·3 | 0·3 | 0·3 | 0·4 | 0·4 | 0·4 | 0·3 | 0·3 | 0·3 | 0·3 |
| 4 | 0·7 | 1·0 | 0·7 | 0·5 | 0·7 | 0·5 | 0·4 | 0·5 | 0·5 | 0·7 | 0·7 | 0·7 |
| 5 | 0·7 | 0·8 | 0·8 | 0·5 | 0·5 | 0·4 | 0·4 | 0·5 | 0·5 | 0·7 | 0·7 | 0·6 |
| 6 | 0·6 | 0·8 | 0·9 | 0·6 | 0·7 | 0·6 | 0·6 | 0·6 | 0·5 | 0·5 | 1·0 | 0·7 |
| 7 | 1·2 | 0·9 | 0·6 | 0·7 | 0·6 | 0·5 | 0·6 | 0·6 | 0·6 | 0·5 | 1·0 | 1·0 |
| 8 | 1·7 | 1·5 | 1·3 | 1·0 | 1·2 | 0·8 | 0·8 | 0·6 | 1·2 | 0·8 | 1·0 | 1·3 |
| 9 | 1·3 | 1·6 | 1·8 | 1·0 | 1·1 | 1·3 | 1·0 | 1·1 | 1·1 | 1·1 | 1·4 | 1·4 |
| 10 | 2·1 | 1·5 | 1·4 | 1·5 | 1·1 | 1·5 | 1·4 | 1·6 | 1·6 | 1·8 | 2·1 | 1·9 |
| 11 | 1·3 | 1·3 | 0·9 | 1·2 | 1·1 | 1·2 | 1·8 | 2·9 | 1·9 | 2·1 | 2·0 | 2·6 |
| 12 | 0·5 | 1·0 | 0·9 | 1·0 | 0·8 | 1·0 | 1·3 | 1·4 | 1·0 | 0·9 | 0·6 | 0·7 |
| 13 | 0·8 | 0·7 | 1·0 | 0·9 | 1·3 | 0·8 | 0·8 | 0·8 | 0·6 | 0·8 | 0·7 | 0·6 |
| 14 | 0·7 | 0·5 | 0·5 | 0·6 | 0·7 | 0·6 | 0·6 | 0·6 | 0·6 | 0·7 | 0·5 | 0·5 |
| 15 | 0·7 | 0·6 | 0·4 | 0·5 | 0·6 | 0·7 | 0·7 | 0·8 | 0·6 | 0·4 | 0·5 | 0·3 |
| 16 | 0·6 | 0·5 | 0·4 | 0·3 | 0·4 | 0·5 | 0·7 | 0·7 | 0·6 | 0·6 | 0·5 | 0·9 |
| 17 | 0·7 | 0·6 | 0·5 | 0·6 | 0·6 | 0·6 | 0·5 | 0·6 | 0·5 | 0·8 | 0·6 | 0·7 |
| 18 | 0·3 | 0·4 | 0·4 | 0·4 | 0·6 | 0·4 | 0·5 | 0·5 | 0·5 | 0·4 | 0·4 | 0·4 |
| 19 | 0·5 | 0·7 | 0·4 | 0·4 | 0·6 | 0·9 | 1·1 | 1·1 | 0·9 | 0·9 | 0·8 | 0·9 |
| 20 | 0·4 | 0·5 | 0·6 | 0·5 | 0·5 | 0·5 | 1·2 | 1·5 | 0·9 | 0·9 | 0·9 | 0·6 |
| 21 | 0·4 | 0·9 | 0·5 | 0·4 | 0·5 | 0·6 | 1·4 | 1·9 | 0·8 | 0·7 | 0·5 | 0·4 |
| 22 | 0·5 | 0·7 | 1·0 | 0·7 | 0·7 | 0·8 | 0·9 | 1·0 | 0·7 | 0·8 | 0·8 | 1·1 |

polar front or near it. For Station 22 (the lightship "Horns Rev") in the south-eastern part of the North Sea the value of $R_1$ is 6·6. For the annual period the temperature maximum in most cases occurs between the 4th and 24th of August. Exceptions are found in the localities 1, 2, 3, 11, 16, 17, and 21.

For the semi-annual period the first temperature maximum occurs between 25th January and 14th February. Exceptions are found in the localities 1, 2, 3, 11, and 22. Notwithstanding the fact that the amplitude $R_2$ for the semi-annual period is of the order of magnitude 0·5 only, the time of occurrence of the temperature maximum is found to be the same for most of the localities. Thus the reality of the semi-annual period cannot be doubted. The principal cause for the semi-annual period may reside in the different stability states of the water in summer and winter. The heating of the water in summer reaches down to a relatively small depth only and accounts for a relatively high increase in the surface temperature. In winter the cooling of the water

reaches down to relatively great depths on account of mixing, and the cooling of the very surface will be less than it would be without the mixing. Possibly also other circumstances, especially the air conditions, are connected with the semi-annual period.

Colums 8 and 9 of Table 2 contain the values of the expressions:—

$$A = \left[\frac{1}{12}\,\Sigma\,(\vartheta - m - R_1 \cos\frac{2\pi}{12}(q - q_1))^2\right]^{1/2} \text{ and}$$

$$B = \left[\frac{1}{12}\,\Sigma\,(\vartheta - m - R_1 \cos\frac{2\pi}{12}(q - q_1) - R_2 \cos\frac{2\pi}{6}(q - q_2))^2\right]^{1/2}$$

These expressions may be interpreted as the standard deviations of the differences between the grand monthly means $\vartheta$ and the monthly means estimated when the annual period only is considered and when both annual and semi-annual periods are considered. Apart from the areas 9, 10, and 11, the means of the values in Columns 8 and 9 of Table 2 are 0·3° and 0·1° respectively.

Columns 10—21 in Table 2 contain the values of the expression $\left[\frac{1}{14}\Sigma\,(t - \vartheta)^2\right]^{1/2}$. These values represent the standard deviations of the monthly means t. For most of the localities they are of the order of magnitude 0·5—1·0. For Area 3, situated on the Equator, all values are less than 0·5. For areas influenced by the polar front — especially Areas 9, 10, and 11 — many of the values are greater than 1·0 and in some few cases greater than 2·0. The standard deviation of a grand mean $\vartheta$ may be estimated from a standard deviation for a monthly mean t by dividing by $\sqrt{14}$. If the above-mentioned areas 9, 10, and 11, are disregarded the standard deviation for a grand monthly mean, $\vartheta$, may thus be estimated at 0·2. Comparing this value with the mean values 0·3 and 0·1 of the differences in Columns 8 and 9 — Areas 9, 10, and 11 excepted — we see that the regular variations of the temperature may be given by the expressions found for the annual and semi-annual period. If the semi-annual period is not considered, the differences between the actual and the calculated values of t are of the order of magnitude 0·3, i. e., greater than the estimated value 0·2 for the standard deviation of a value of $\vartheta$.

### 3. Stability of the Anomalies of Temperature.

The investigation is based on calculated values for the correlation between the monthly anomalies $t - \vartheta$ mentioned in the introduction. For each locality the anomalies for months with the same name are correlated with the anomalies for the following months. For instance, the anomalies for April are correlated with the anomalies for May, June, and so on. The values found for the correlation coefficients are then averaged.

For each locality, $12 \times 14 = 168$ anomalies $t - \vartheta$ are at disposal. For convenience an anomaly $(t - \vartheta)$ is designated by x. The month to

which it refers is given by an index in accordance with the form A below. In this form each of the anomalies $x_{13} - x_{168}$ are recorded in two different places.

**Form A.**

| Year | Month J | F | M | A | M | J | J | A | S | O | N | D | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1900 | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_7$ | $x_8$ | $x_9$ | $x_{10}$ | $x_{11}$ | $x_{12}$ | |
| | $x_{13}$ | $x_{14}$ | $x_{15}$ | $x_{16}$ | $x_{17}$ | $x_{18}$ | $x_{19}$ | $x_{20}$ | $x_{21}$ | $x_{22}$ | $x_{23}$ | $x_{24}$ | 1901 |
| 1901 | $x_{13}$ | $x_{14}$ | $x_{15}$ | $x_{16}$ | $x_{17}$ | $x_{18}$ | $x_{19}$ | $x_{20}$ | $x_{21}$ | $x_{22}$ | $x_{23}$ | $x_{24}$ | |
| | $x_{25}$ | $x_{26}$ | $x_{27}$ | $x_{28}$ | $x_{29}$ | $x_{30}$ | $x_{31}$ | $x_{32}$ | $x_{33}$ | $x_{34}$ | $x_{35}$ | $x_{36}$ | 1902 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 1912 | $x_{145}$ | $x_{146}$ | $x_{147}$ | $x_{148}$ | $x_{149}$ | $x_{150}$ | $x_{151}$ | $x_{152}$ | $x_{153}$ | $x_{154}$ | $x_{155}$ | $x_{156}$ | |
| | $x_{157}$ | $x_{158}$ | $x_{159}$ | $x_{160}$ | $x_{161}$ | $x_{162}$ | $x_{163}$ | $x_{164}$ | $x_{165}$ | $x_{166}$ | $x_{167}$ | $x_{168}$ | 1913 |
| 1913 | $x_{157}$ | $x_{158}$ | $x_{159}$ | $x_{160}$ | $x_{161}$ | $x_{162}$ | $x_{163}$ | $x_{164}$ | $x_{165}$ | $x_{166}$ | $x_{167}$ | $x_{168}$ | |

Correlation coefficients are calculated for anomalies recorded in the columns in Form A. Designating by p and q two different indices for x, where $p \leq 12$ and where $p < q \leq 24$ we obtain a correlation coefficient $r_{pq}$ from:—

$$r_{pq} = \frac{x_p \cdot x_q + x_{p+12} \cdot x_{q+12} + x_{p+24} \cdot x_{q+24} + \cdots \quad \cdot \cdot}{(x_p^2 + x_{p+12}^2 + x_{p+24}^2 + \cdots \cdot)^{1/2} \cdot (x_q^2 + x_{q+12}^2 + x_{q+24}^2 + \cdots \cdot)^{1/2}}$$

For $q \leq 12$, 14 pairs of values are at disposal for the calculation of $r_{pq}$, the last pair being $x_{p+156}$ and $x_{q+156}$. For $q > 12$, 13 pairs only are at disposal, the last pair being $x_{p+144}$ and $x_{q+144}$.[1])

A correlation coefficient $r_{pq}$ is said to refer to the interval of $q - p$ months. For each locality the values of $r_{pq}$ may be recorded as shown in Form B.

At the top of the form, the months in two successive years are indicated by their names and by the numbers 1, 2, 3, ... 24. A correlation coefficient $r_{pq}$ is placed midway between the columns for the months p and q. Coefficients on the same horizontal line refer to the same interval of time, viz., $q - p$ months, recorded on the left-hand side of the form.

Instead of Form B a slightly different Form C has been used for recording the calculated correlation coefficients $r_{pq}$. Form C differs from Form B in that the coefficients $r_{1214}$, $r_{1215}$, $r_{1115}$, $r_{1216}$, etc. are placed on the left-hand side of the form, whereas they are placed on the right-

[1]) Strictly speaking instead of the values $t - \vartheta$ we should in this case ($q > 12$) have used for $x$ $t - \vartheta'$ where $\vartheta'$ is the grand monthly mean for the 13 years in question. As this would certainly not influence the results to any essential degree we have for the sake of simplicity used the values of $t - \vartheta$ throughout the investigation.

**Form B.**

| q—p | J 1. | F 2 | M 3 | A 4 | M 5 | J 6 | J 7 | A 8 | S 9 | O 10 | N 11 | D 12 | J 13 | F 14 | M 15 | ... | D 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $r_{12}$ | $r_{23}$ | $r_{34}$ | $r_{45}$ | $r_{56}$ | $r_{67}$ | $r_{78}$ | $r_{89}$ | $r_{9\,10}$ | $r_{10\,11}$ | $r_{11\,12}$ | $r_{12\,13}$ | | | | | |
| 2 | $r_{13}$ | $r_{24}$ | $r_{35}$ | $r_{46}$ | $r_{57}$ | $r_{68}$ | $r_{79}$ | $r_{8\,10}$ | $r_{9\,11}$ | $r_{10\,12}$ | $r_{11\,13}$ | $r_{12\,14}$ | | | | | |
| 3 | $r_{14}$ | $r_{25}$ | $r_{36}$ | $r_{47}$ | $r_{58}$ | $r_{69}$ | $r_{7\,10}$ | $r_{8\,11}$ | $r_{9\,12}$ | $r_{10\,13}$ | $r_{11\,14}$ | $r_{12\,15}$ | | | | | |
| 4 | $r_{15}$ | $r_{26}$ | $r_{37}$ | $r_{48}$ | $r_{59}$ | $r_{6\,10}$ | $r_{7\,11}$ | $r_{8\,12}$ | $r_{9\,13}$ | $r_{10\,14}$ | $r_{11\,15}$ | $r_{12\,16}$ | | | | | |
| 5 | $r_{16}$ | $r_{27}$ | $r_{38}$ | $r_{49}$ | $r_{5\,10}$ | $r_{6\,11}$ | $r_{7\,12}$ | $r_{8\,13}$ | $r_{9\,14}$ | $r_{10\,15}$ | $r_{11\,16}$ | $r_{12\,17}$ | | | | | |
| 6 | $r_{17}$ | $r_{28}$ | $r_{39}$ | $r_{4\,10}$ | $r_{5\,11}$ | $r_{6\,12}$ | $r_{7\,13}$ | $r_{8\,14}$ | $r_{9\,15}$ | $r_{10\,16}$ | $r_{11\,17}$ | $r_{12\,18}$ | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | | |

**Form C.**

| q—p | Jan. 1 | Feb. 2 | Mar. 3 | Apr. 4 | May 5 | June 6 | July 7 | Aug. 8 | Sep. 9 | Oct. 10 | Nov. 11 | Dec. 12 | Mean for the year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $r_{12}$ | $r_{23}$ | $r_{34}$ | $r_{45}$ | $r_{56}$ | $r_{67}$ | $r_{78}$ | $r_{89}$ | $r_{9\,10}$ | $r_{10\,11}$ | $r_{11\,12}$ | $r_{12\,13}$ | $r_1$ |
| 2 | $r_{12\,14}$ | $r_{13}$ | $r_{24}$ | $r_{35}$ | $r_{46}$ | $r_{57}$ | $r_{68}$ | $r_{79}$ | $r_{8\,10}$ | $r_{9\,11}$ | $r_{10\,12}$ | $r_{11\,13}$ | $r_2$ |
| 3 | $r_{12\,15}$ | $r_{14}$ | $r_{25}$ | $r_{36}$ | $r_{47}$ | $r_{58}$ | $r_{69}$ | $r_{7\,10}$ | $r_{8\,11}$ | $r_{9\,12}$ | $r_{10\,13}$ | $r_{11\,14}$ | $r_3$ |
| 4 | $r_{11\,15}$ | $r_{12\,16}$ | $r_{15}$ | $r_{26}$ | $r_{37}$ | $r_{48}$ | $r_{59}$ | $r_{6\,10}$ | $r_{7\,11}$ | $r_{8\,12}$ | $r_{9\,13}$ | $r_{10\,14}$ | $r_4$ |
| 5 | $r_{11\,16}$ | $r_{12\,17}$ | $r_{16}$ | $r_{27}$ | $r_{38}$ | $r_{49}$ | $r_{5\,10}$ | $r_{6\,11}$ | $r_{7\,12}$ | $r_{8\,13}$ | $r_{9\,14}$ | $r_{10\,15}$ | $r_5$ |
| 6 | $r_{10\,16}$ | $r_{11\,17}$ | $r_{12\,18}$ | $r_{17}$ | $r_{28}$ | $r_{39}$ | $r_{4\,10}$ | $r_{5\,11}$ | $r_{6\,12}$ | $r_{7\,13}$ | $r_{8\,14}$ | $r_{9\,15}$ | $r_6$ |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . |

hand side in Form B. Furthermore, a column headed "Mean for the year" on the right-hand side of Form C contains the means $r_1$, $r_2$, $r_3$, ... of the coefficients for the values 1, 2, 3, ... of q — p.

In accordance with Form C the calculated values of $100\, r_{pq}$ are given in Table 3 for the localities stated in Table 1.

An inspection of the values for $r_{pq}$ shows that their variation must be very largely subject to accidental causes. This is easily understood, as each value for $r_{pq}$ is based on 13 or 14 pairs of anomalies only. A few anomalies deviating to a particularly high extent from the normal may make their influence felt in a series of values for $r_{pq}$ in Table 3. This is, for instance, the case with the anomalies in the month of April for Area 12. For this area the mean temperatures for the months March, April, and May in 1903 are 11·2°, 14·6° and 11·9° with anomalies —0·5°, 2·3°, and —1·0°. For the same months in 1909 the mean temperatures are 12·5°, 10·9°, and 13·4°, with the anomalies 0·8°, —1·4°, and 0·5°. Thus the mean temperature for April in 1903 was exceptionally high and in 1909 exceptionally low. This is the cause of the peculiar distribution of the positive and negative values of $r_{pq}$ in Table 3 for Area 12. The values $r_{45} = -0{\cdot}03$, $r_{46} = 0{\cdot}21$, $r_{47} = -0{\cdot}39$, $r_{48} = -0{\cdot}41$, $r_{49} = -0{\cdot}44$, $r_{410} = -0{\cdot}48$, $r_{411} = -0{\cdot}12$, $r_{412} = -0{\cdot}55$, $r_{413} = -0{\cdot}07$ lie on a sloping line. With one exception only these values are all of negative sign. The values of $r_{pq}$ in the neighbourhood of this line are mainly of positive sign. Similar characteristic distributions of particularly high or low (negative) values for $r_{pq}$ along sloping lines are found at many places in Table 3. This is in accordance with the fact that the anomaly for a month has been used for calculating the values of $r_{pq}$ along such a line as seen in Form C.

Such exceptionally high or low anomalies as those mentioned above are ordinarily to be considered as accidental. Their exceptional value may be due to the temperature conditions themselves but may also arise from the distribution in space and time of the temperature observations used for the computation of the monthly means. For some localities — Danish, Icelandic, and Norwegian coastal stations — the monthly means are computed from daily observations. For the rest of the localities — the areas — the monthly means are based on fewer observations distributed over the area. The number, n, of observations on which the monthly means are based is stated in the Bulletin. Observations from areas marked by D are collected by Deutsche Seewarte, and with regard to these observations it is stated in the Bulletin that the average date for each monthly mean, t, was calculated and that of these average dates by far the greater number were found to lie close to the middle of the month. A similar statement is not found for the other areas. The number, n, of the observations used for the calculation of the monthly temperature means is, however, ordinarily so great that the value found may be considered as applicable to the middle of the month.

Disregarding the accidental variations of $r_{pq}$, one has to look for

**Table 3. Values of $100 \cdot r_{pq}$ as defined in the Explanation of Forms B and C, page 24.**

| Locality | q − p | Month J | F | M | A | M | J | J | A | S | O | N | D | Mean for the year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 70 | 65 | 77 | 08 | 12 | 46 | 49 | 38 | 53 | 31 | 44 | 33 | 44 |
| 36° – 37° N. | 2 | 10 54 | 70 | 08 | −12 | 01 | 23 | 25 | 55 | 13 | 32 | −19 | | 22 |
| 12° – 15° W. | 3 | 13 | 55 | 01 | −08 | −18 | −56 | −05 | 11 | 16 | −04 | −32 | 06 | −02 |
| D | 4 | 17 36 | 29 | −27 | −28 | −42 | −63 | 12 | 09 | 14 | −02 | −24 | | −06 |
| | 5 | 30 | 54 | 35 | 08 | −42 | −13 | −27 | −40 | 38 | −09 | −27 | 19 | 02 |
| | 6 | 43 26 | 12 | 33 | −14 | 17 | −46 | 03 | −15 | 59 | −18 | 21 | | 07 |
| 2 | 1 | 73 | 90 | 67 | 88 | 65 | 56 | 39 | 69 | 71 | 40 | 08 | 47 | 59 |
| 20° – 21° N. | 2 | −03 57 | 85 | 71 | 62 | 43 | 49 | −04 | 19 | 35 | −04 | −08 | | 34 |
| 20° – 23° W. | 3 | −04 | 75 | 88 | 31 | 53 | 30 | 34 | −26 | 07 | −05 | 19 | −36 | 22 |
| D | 4 | −23 03 | 74 | 65 | 42 | 39 | 03 | −16 | −09 | 10 | 26 | 06 | | 18 |
| | 5 | −16 | 15 | 50 | 57 | 08 | 01 | −24 | −18 | 17 | 51 | −08 | 07 | 12 |
| | 6 | 13 −23 | −18 | 36 | 28 | −31 | −37 | −48 | −12 | −12 | 17 | −25 | | −09 |
| | 7 | 16 | −41 −29 | 44 | −10 | −41 | −23 | −22 | −25 | −03 | −15 | −04 | | −13 |
| | 8 | 14 08 | −65 | 10 | 35 | −39 | −44 | −38 | −03 | −11 | −10 | 26 | | −10 |
| | 9 | 08 | 16 01 | 28 | −01 | −45 | −09 | 12 | 25 | 13 | 00 | 30 | | 02 |
| 3 | 1 | 71 | 68 | 88 | 53 | 74 | 57 | 48 | 45 | 66 | 85 | 87 | 81 | 69 |
| 0° – 1° H. | 2 | 66 57 | 70 | 44 | 62 | 53 | 73 | 64 | 63 | 48 | 88 | 64 | | 63 |
| 29° – 32° W. | 3 | 78 | 48 | 40 | 51 | 63 | 33 | 66 | 58 | 79 | 64 | 55 | 45 | 57 |
| D | 4 | 47 60 | 32 | 59 | 61 | 61 | 34 | 34 | 54 | 68 | 50 | 50 | | 51 |
| | 5 | 31 | 49 | 47 | 68 | 61 | 40 | 02 | 45 | 58 | 44 | 13 | 58 | 43 |
| | 6 | 44 19 | 58 | 57 | 69 | 17 | 51 | 15 | 47 | 65 | 18 | 43 | | 42 |
| | 7 | 52 | 45 | 64 | 51 | 59 | 33 | 65 | 11 | 45 | 38 | 20 | 31 | 43 |
| | 8 | 34 66 | 29 | 52 | 45 | 68 | 57 | 50 | 39 | 03 | 41 | 04 | | 40 |
| | 9 | 36 | 58 | 47 | 45 | 34 | 85 | 32 | 40 | 03 | 17 | 40 | 06 | 36 |
| 4 | 1 | 45 | 45 | 14 | 25 | 53 | 17 | 44 | 49 | 29 | 03 | 44 | 44 | 32 |
| 22° – 25° H. | 2 | 36 18 | 26 | 11 | 42 | 15 | 29 | 57 | 26 | 21 | 51 | 03 | | 19 |
| 73° – 77° W. | 3 | 28 | 33 | 12 | 02 | 28 | 05 | 40 | 07 | 44 | 06 | 18 | 08 | 17 |
| H | 4 | 00 52 | 33 | 37 | 58 | 46 | 13 | 09 | 48 | 19 | 03 | 52 | | 19 |
| | 5 | 23 | 05 26 | 35 | 17 | 26 | 15 | 42 | 24 | 08 | 67 | 55 | | 21 |
| | 6 | 31 15 | 03 | 08 | 19 | 23 | −04 | 39 | 46 | −13 | 32 | 72 | | 19 |

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| 5 | 1 | | 57 | | 31 | | 15 | | 41 | | 37 | | 01 | | 27 | | 16 | | 50 |
| 25°—28°N. | 2 | 67 | | 61 | | —18 | | —03 | | 48 | | 19 | | 04 | | 73 | | —11 | |
| 73°—77°W. | 3 | | 34 | | 12 | | —05 | | —44 | | 67 | | —09 | | 51 | | 46 | | 54 |
| H | 4 | 48 | | 00 | | —09 | | —62 | | 33 | | 23 | | 46 | | 27 | | 36 | |
| | 5 | | 56 | | 28 | | —43 | | —03 | | 08 | | 71 | | 13 | | 37 | | —17 |
| | 6 | 36 | | 07 | | —16 | | 36 | | 32 | | 02 | | 47 | | —01 | | 48 | |

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| 6 | 1 | | 59 | | 46 | | 14 | | 38 | | 39 | | —10 | | 43 | | 33 | | 24 |
| 28°—31°N. | 2 | 55 | | 04 | | —32 | | —28 | | 34 | | —10 | | —11 | | 34 | | 07 | |
| 73°—77°W. | 3 | | 45 | | 08 | | —21 | | —29 | | 19 | | —45 | | 05 | | 43 | | 28 |
| H | 4 | 21 | | 27 | | —04 | | —18 | | 22 | | —10 | | 32 | | 46 | | 18 | |
| | 5 | | —08 | | 07 | | —27 | | 14 | | —08 | | 10 | | 20 | | 52 | | —04 |
| | 6 | 16 | | —56 | | 12 | | 07 | | —11 | | —18 | | 07 | | 05 | | 08 | |

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| 7 | 1 | | 60 | | 19 | | 61 | | 30 | | 26 | | 04 | | 72 | | 45 | | 27 |
| 31°—34°N. | 2 | 57 | | 28 | | 06 | | 08 | | 60 | | —05 | | 10 | | 36 | | 57 | |
| 73°—77°W. | 3 | | 41 | | 47 | | 07 | | 16 | | —09 | | —29 | | 04 | | 40 | | 39 |
| H | 4 | 18 | | 36 | | 42 | | —09 | | 12 | | —09 | | 16 | | 27 | | 33 | |
| | 5 | | 17 | | 06 | | 52 | | —30 | | —01 | | —04 | | —14 | | 72 | | 02 |
| | 6 | 07 | | —18 | | —15 | | —39 | | —01 | | —08 | | —29 | | 24 | | 52 | |

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| 8 | 1 | | 09 | | 04 | | 29 | | 18 | | 51 | | 53 | | 40 | | 02 | | 26 |
| 34°—37°N. | 2 | 00 | | 30 | | 11 | | 32 | | 27 | | 53 | | 08 | | 04 | | 00 | |
| 73°—77°W. | 3 | | 13 | | 46 | | —11 | | 22 | | 03 | | 20 | | 17 | | —30 | | 12 |
| H | 4 | 48 | | 31 | | 65 | | —22 | | 09 | | —03 | | 37 | | —13 | | 33 | |
| | 5 | | 13 | | 38 | | 49 | | —36 | | —06 | | —11 | | —37 | | 22 | | 33 |
| | 6 | 01 | | —03 | | 28 | | 35 | | —16 | | 29 | | 21 | | 08 | | —22 | |

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| 9 | 1 | | 64 | | 05 | | 48 | | 18 | | 59 | | 39 | | 42 | | 53 | | 59 |
| 37°—40°N. | 2 | 30 | | 57 | | —12 | | 24 | | 18 | | 03 | | 35 | | —14 | | 55 | |
| 73°—77°W. | 3 | | —34 | | 45 | | 57 | | —11 | | —03 | | —05 | | 17 | | —01 | | 29 |
| H | 4 | 12 | | 24 | | 44 | | —03 | | —22 | | 28 | | 14 | | 72 | | 12 | |
| | 5 | | 52 | | 30 | | —16 | | —23 | | —49 | | 32 | | 24 | | 42 | | —14 |
| | 6 | 11 | | 04 | | —13 | | —21 | | —19 | | —06 | | 44 | | 41 | | 24 | |

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| 5 | 1 | | 31 | | 15 | | 41 | | 37 | | 01 | | 27 | | 16 | | 50 | | 11 |
| 25°—28°N. | 2 | 61 | | —18 | | —03 | | 48 | | 19 | | 04 | | 73 | | —11 | | 28 | |
| 73°—77°W. | 3 | | 12 | | —05 | | —44 | | 67 | | —09 | | 51 | | 46 | | 54 | | 00 |
| H | 4 | 00 | | —09 | | —62 | | 33 | | 23 | | 46 | | 27 | | 36 | | —11 | |
| | 5 | | 28 | | —43 | | —03 | | 08 | | 71 | | 13 | | 37 | | —17 | | 13 |
| | 6 | 07 | | —16 | | 36 | | 32 | | 02 | | 47 | | —01 | | 48 | | 24 | |

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| 6 | 1 | | 46 | | 14 | | 38 | | 39 | | —10 | | 43 | | 33 | | 24 | | 30 |
| 28°—31°N. | 2 | 04 | | —32 | | —28 | | 34 | | —10 | | —11 | | 34 | | 07 | | —17 | |
| 73°—77°W. | 3 | | 08 | | —21 | | —29 | | 19 | | —45 | | 05 | | 43 | | 28 | | —25 |
| H | 4 | 27 | | —04 | | —18 | | 22 | | —10 | | 32 | | 46 | | 18 | | —15 | |
| | 5 | | 07 | | —27 | | 14 | | —08 | | 10 | | 20 | | 52 | | —04 | | —22 |
| | 6 | —56 | | 12 | | 07 | | —11 | | —18 | | 07 | | 05 | | 08 | | 07 | |

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| 7 | 1 | | 19 | | 61 | | 30 | | 26 | | 04 | | 72 | | 45 | | 27 | | 34 |
| 31°—34°N. | 2 | 28 | | 06 | | 08 | | 60 | | —05 | | 10 | | 36 | | 57 | | 11 | |
| 73°—77°W. | 3 | | 47 | | 07 | | 16 | | —09 | | —29 | | 04 | | 40 | | 39 | | —26 |
| H | 4 | 36 | | 42 | | —09 | | 12 | | —09 | | 16 | | 27 | | 33 | | —10 | |
| | 5 | | 06 | | 52 | | —30 | | —01 | | —04 | | —14 | | 72 | | 02 | | 07 |
| | 6 | —18 | | —15 | | —39 | | —01 | | —08 | | —29 | | 24 | | 52 | | 19 | |

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| 8 | 1 | | 04 | | 29 | | 18 | | 51 | | 53 | | 40 | | 02 | | 26 | | 33 |
| 34°—37°N. | 2 | 30 | | 11 | | 32 | | 27 | | 53 | | 08 | | 04 | | 00 | | 46 | |
| 73°—77°W. | 3 | | 46 | | —11 | | 22 | | 03 | | 20 | | 17 | | —30 | | 12 | | 03 |
| H | 4 | 31 | | 65 | | —22 | | 09 | | —03 | | 37 | | —13 | | 33 | | 35 | |
| | 5 | | 38 | | 49 | | —36 | | —06 | | —11 | | —37 | | 22 | | 33 | | —43 |
| | 6 | —03 | | 28 | | 35 | | —16 | | 29 | | 21 | | 08 | | —22 | | 24 | |

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| 9 | 1 | | 05 | | 48 | | 18 | | 59 | | 39 | | 42 | | 53 | | 59 | | 53 |
| 37°—40°N. | 2 | 57 | | —12 | | 24 | | 18 | | 03 | | 35 | | —14 | | 55 | | 25 | |
| 73°—77°W. | 3 | | 45 | | 57 | | —11 | | —03 | | —05 | | 17 | | —01 | | 29 | | 25 |
| H | 4 | 24 | | 44 | | —03 | | —22 | | 28 | | 14 | | 72 | | 12 | | 15 | |
| | 5 | | 30 | | —16 | | —23 | | —49 | | 32 | | 24 | | 42 | | —14 | | 07 |
| | 6 | 04 | | —13 | | —21 | | —19 | | —06 | | 44 | | 41 | | 24 | | 04 | |

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| 5 | 1 | | 15 | | 71 | | 31 | | | | | | | | | | | | |
| 25°—28°N. | 2 | | 17 | | 43 | | 27 | | | | | | | | | | | | |
| 73°—77°W. | 3 | | 43 | | 11 | | 22 | | | | | | | | | | | | |
| H | 4 | | 38 | | 32 | | 17 | | | | | | | | | | | | |
| | 5 | | 13 | | 33 | | 52 | | 21 | | | | | | | | | | |
| | 6 | | 24 | | —10 | | 53 | | 22 | | | | | | | | | | |

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| 6 | 1 | | 03 | | 30 | | 29 | | | | | | | | | | | | |
| 28°—31°N. | 2 | | 29 | | 05 | | 06 | | | | | | | | | | | | |
| 73°—77°W. | 3 | | 32 | | 09 | | 06 | | | | | | | | | | | | |
| H | 4 | | 34 | | 17 | | 14 | | | | | | | | | | | | |
| | 5 | | —22 | | —20 | | 14 | | 02 | | | | | | | | | | |
| | 6 | | 07 | | —18 | | —09 | | —04 | | | | | | | | | | |

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| 7 | 1 | | 49 | | 46 | | 39 | | | | | | | | | | | | |
| 31°—34°N. | 2 | | 18 | | 26 | | 26 | | | | | | | | | | | | |
| 73°—77°W. | 3 | | 28 | | 33 | | 16 | | | | | | | | | | | | |
| H | 4 | | —23 | | 05 | | 12 | | | | | | | | | | | | |
| | 5 | | —29 | | 16 | | 08 | | | | | | | | | | | | |
| | 6 | | —23 | | —18 | | —04 | | | | | | | | | | | | |

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| 8 | 1 | | 03 | | 11 | | 23 | | | | | | | | | | | | |
| 34°—37°N. | 2 | | 00 | | 03 | | 18 | | | | | | | | | | | | |
| 73°—77°W. | 3 | | —27 | | —11 | | 05 | | | | | | | | | | | | |
| H | 4 | | 02 | | —12 | | 18 | | | | | | | | | | | | |
| | 5 | | 01 | | —18 | | 00 | | | | | | | | | | | | |
| | 6 | | 24 | | —14 | | 69 | | 13 | | | | | | | | | | |

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| 9 | 1 | | 53 | | 46 | | 44 | | | | | | | | | | | | |
| 37°—40°N. | 2 | | 25 | | 43 | | 16 | | 23 | | | | | | | | | | |
| 73°—77°W. | 3 | | 25 | | 22 | | —05 | | 11 | | | | | | | | | | |
| H | 4 | | 15 | | —06 | | 29 | | 18 | | | | | | | | | | |
| | 5 | | 07 | | 13 | | 07 | | 09 | | | | | | | | | | |
| | 6 | | 04 | | —17 | | —39 | | 01 | | | | | | | | | | |

**Table 3** continued.

| Locality | q—p | Month J | F | M | A | M | J | J | A | S | O | N | D | Mean for the year |
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| 10 | 1 | —17 | 07 | 64 | 00 | 25 | 52 | 41 | 57 | 70 | 71 | 60 | 25 | 38 |
| 40°—43°N. | 2 | —23 | 04 | 38 | —01 | —03 | 32 | 22 | 11 | 38 | 52 | 58 | 08 | 20 |
| 57°—60°W. | 3 | 11 | 07 | —48 | —06 | —24 | 57 | —19 | —21 | 45 | 69 | 62 | —36 | 08 |
| H | 4 | 52 | —52 | 33 | 10 | —52 | —13 | 47 | —05 | —19 | 20 | 69 | —37 | 04 |
| | 5 | —01 | 14 | —12 | —16 | —24 | —26 | 27 | —05 | —29 | 47 | —45 | 29 | —03 |
| | 6 | 11 | 15 | 13 | —03 | —33 | —17 | —06 | 42 | —15 | 30 | —03 | 19 | 04 |
| 11 | 1 | 30 | 42 | 58 | 65 | 05 | 30 | 74 | 44 | 90 | 83 | 71 | 18 | 51 |
| 43°—47°N. | 2 | —03 | 14 | 45 | 41 | 01 | —21 | 41 | 30 | 33 | 68 | 45 | 43 | 28 |
| 42°—45°W. | 3 | 20 | 37 | 19 | 21 | —33 | —22 | 07 | 28 | 16 | 44 | 41 | 07 | 15 |
| H | 4 | 28 | 30 | 49 | 21 | 07 | —52 | 14 | 01 | 14 | 13 | 27 | 09 | 14 |
| | 5 | 65 | 61 | 23 | —24 | —11 | —04 | 24 | —05 | 15 | —03 | —03 | —05 | 11 |
| | 6 | 34 | 82 | 05 | 03 | —23 | —18 | 05 | 03 | —40 | 28 | —15 | —11 | 04 |
| 12 | 1 | 26 | 71 | 28 | —03 | 73 | 56 | 77 | 80 | 68 | 55 | 47 | 60 | 53 |
| 47°—50°N. | 2 | 56 | 40 | 21 | 57 | 21 | 55 | 33 | 88 | 45 | 35 | 37 | 22 | 42 |
| 30°—33°W. | 3 | 48 | 38 | 53 | 59 | —39 | 38 | 51 | 60 | 19 | 36 | 26 | 35 | 35 |
| H | 4 | 09 | 19 | 21 | 51 | 27 | —41 | 55 | 36 | 15 | 09 | 34 | 21 | 21 |
| | 5 | —16 | 65 | 44 | 43 | 27 | —44 | 46 | 21 | 36 | 23 | 26 | 03 | 23 |
| | 6 | 43 | 52 | 57 | 14 | 34 | 27 | —48 | —03 | 32 | 52 | —05 | 27 | 24 |
| | 7 | 44 | 27 | 34 | 32 | 34 | 25 | —12 | 15 | 60 | 26 | 12 | 36 | 28 |
| | 8 | 44 | 48 | 49 | 26 | 37 | 52 | 06 | —55 | 35 | 27 | 24 | 09 | 25 |
| | 9 | 51 | 33 | 70 | 39 | 32 | 06 | —04 | —07 | 39 | 37 | 40 | 36 | 31 |
| 13 | 1 | 71 | 39 | 79 | 44 | 73 | 42 | 82 | 76 | 68 | 13 | 67 | 63 | 60 |
| 54°—56°N. | 2 | 55 | 52 | 52 | 29 | 60 | 23 | 52 | 85 | 75 | 06 | 25 | 50 | 47 |
| 27°—29°W. | 3 | 33 | 74 | 39 | 37 | 17 | 39 | 58 | 61 | —01 | 25 | 12 | 18 | 34 |
| Da | 4 | 05 | 16 | 54 | 72 | 13 | 23 | 39 | 55 | —05 | 11 | 26 | 33 | 28 |
| | 5 | 09 | 19 | 72 | 59 | 23 | 33 | 55 | 28 | 07 | 18 | 50 | —15 | 30 |
| | 6 | 06 | 13 | 45 | 43 | 52 | 20 | 17 | 24 | 36 | —03 | 42 | —24 | 23 |
| | 7 | —35 | 27 | 35 | 39 | 53 | 02 | —09 | 61 | 25 | 33 | —19 | 17 | 19 |
| | 8 | —26 | 07 | 42 | 40 | 59 | 47 | —38 | 18 | 19 | 49 | —22 | 08 | 17 |
| | 9 | 24 | —17 | 46 | 39 | 46 | —18 | 00 | 04 | 40 | —08 | —04 | —24 | 11 |

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| 14 | 1 | | 35 | | 20 | | 75 | | 74 | | 48 | | 66 | | 59 | | 34 | | 20 | | 14 | | 25 | | 32 | | 42 |
| 57°—58°N. | 2 | 63 | | 55 | | 42 | | 64 | | 65 | | 41 | | 18 | | 37 | | 02 | | —13 | | 11 | | 09 | | 33 |
| 16°—20°W. | 3 | | 42 | | 48 | | 47 | | 56 | | 56 | | 26 | | 60 | | 07 | | —10 | | 21 | | 02 | | 38 | | 33 |
| Da | 4 | 18 | | 41 | | 30 | | 40 | | 59 | | 36 | | 32 | | 11 | | 42 | | 62 | | —30 | | 07 | | 29 |
| | 5 | | —01 | | 30 | | 45 | | 03 | | 49 | | 45 | | 06 | | 24 | | 77 | | 18 | | —16 | | 16 | | 25 |
| | 6 | 01 | | 20 | | 34 | | 37 | | —24 | | 53 | | 16 | | 11 | | 44 | | 44 | | 38 | | 24 | | 25 |
| | 7 | | —42 | | 39 | | —09 | | 36 | | 31 | | —20 | | 09 | | 61 | | 07 | | 60 | | 15 | | —08 | | 15 |
| | 8 | 18 | | 43 | | 25 | | —01 | | 11 | | 33 | | —02 | | 45 | | 18 | | 20 | | 62 | | 23 | | 25 |
| | 9 | | 16 | | 15 | | 27 | | 24 | | 01 | | 41 | | 51 | | 11 | | 67 | | 61 | | 41 | | 32 | | 32 |
| 15 | 1 | | —08 | | 00 | | 26 | | 45 | | 42 | | 88 | | 73 | | 80 | | 23 | | 13 | | 19 | | —01 | | 33 |
| 58°—60°N. | 2 | 00 | | —03 | | 32 | | 45 | | 16 | | 36 | | 81 | | 78 | | 21 | | 02 | | 31 | | —12 | | 27 |
| 9°—11°W. | 3 | | 06 | | 26 | | 22 | | 60 | | 26 | | 13 | | 76 | | —07 | | —27 | | 34 | | —05 | | 24 | | 21 |
| Da | 4 | —06 | | 02 | | 49 | | —27 | | 44 | | —06 | | 33 | | —18 | | 01 | | 45 | | 30 | | —07 | | | | 12 |
| | 5 | | 27 | | 66 | | 33 | | —15 | | 26 | | 24 | | —46 | | —16 | | 52 | | 08 | | 30 | | 12 | | 17 |
| | 6 | 16 | | —01 | | 40 | | 55 | | —36 | | 33 | | —26 | | 16 | | 43 | | 20 | | 07 | | 35 | | | | 17 |
| | 7 | | 35 | | 14 | | 10 | | 31 | | —16 | | —42 | | 19 | | —34 | | 34 | | 22 | | 48 | | 23 | | 12 |
| | 8 | 72 | | 18 | | —13 | | 30 | | 47 | | 12 | | —22 | | 03 | | 32 | | 23 | | 26 | | 07 | | | | 20 |
| | 9 | | —02 | | —19 | | 13 | | 24 | | —01 | | 26 | | 19 | | 23 | | 63 | | 36 | | 16 | | 63 | | 22 |
| 16 | 1 | | —08 | | 46 | | 67 | | 71 | | 74 | | 52 | | 62 | | 78 | | 39 | | 54 | | 45 | | 18 | | 50 |
| 59°—60°N. | 2 | 37 | | —51 | | 18 | | 48 | | 32 | | 74 | | 71 | | 59 | | 34 | | 19 | | 44 | | 23 | | | | 34 |
| 1°— 3°W. | 3 | | —05 | | —03 | | —17 | | 13 | | 32 | | 53 | | 43 | | —05 | | —03 | | 15 | | 07 | | 57 | | 16 |
| Da | 4 | 42 | | —07 | | —25 | | —42 | | 29 | | 07 | | 35 | | 31 | | —03 | | 03 | | 33 | | 22 | | | | 10 |
| | 5 | | 26 | | —30 | | —46 | | —20 | | —05 | | —09 | | —14 | | 02 | | —23 | | 12 | | —41 | | 11 | | —11 |
| | 6 | 28 | | —19 | | —34 | | —13 | | —39 | | —19 | | —34 | | —17 | | —26 | | 32 | | —39 | | —04 | | | | —15 |
| | 7 | | 15 | | —51 | | —28 | | —38 | | —57 | | —43 | | —39 | | —51 | | —04 | | —34 | | 13 | | 33 | | —24 |
| | 8 | 05 | | —21 | | —03 | | —45 | | —06 | | —23 | | —39 | | —52 | | —11 | | —31 | | —15 | | 67 | | | | —14 |
| | 9 | | —26 | | 09 | | —60 | | —58 | | 03 | | —47 | | —28 | | —31 | | —26 | | 31 | | 18 | | 45 | | —14 |
| 17 | 1 | | 20 | | 52 | | 22 | | 48 | | 54 | | 56 | | 24 | | 65 | | —02 | | 62 | | 26 | | 51 | | 40 |
| 63°26′N. | 2 | 22 | | 28 | | 33 | | 36 | | 50 | | 46 | | 32 | | 34 | | —32 | | —27 | | 45 | | —03 | | | | 22 |
| 20°15′W. | 3 | | 41 | | 52 | | 45 | | 13 | | 44 | | —24 | | 15 | | —21 | | —50 | | —08 | | 24 | | 50 | | 15 |
| Vestmanø | 4 | —16 | | 26 | | 29 | | 10 | | 33 | | —17 | | —36 | | —50 | | —20 | | 26 | | —18 | | 38 | | | | 00 |
| | 5 | | 24 | | 03 | | 19 | | 18 | | —14 | | —41 | | —24 | | —42 | | —31 | | 15 | | —09 | | —06 | | —07 |
| | 6 | 52 | | —12 | | 14 | | 29 | | —36 | | 22 | | —05 | | —24 | | —42 | | 13 | | —03 | | 02 | | | | 01 |
| | 7 | | 08 | | —23 | | 32 | | —35 | | —22 | | 33 | | 05 | | —31 | | 27 | | 42 | | 46 | | 04 | | 07 |
| | 8 | 34 | | 19 | | 13 | | —35 | | —16 | | 25 | | —07 | | —03 | | 06 | | —03 | | —01 | | —17 | | | | 01 |
| | 9 | | 27 | | 10 | | —24 | | —02 | | 15 | | —02 | | 09 | | 45 | | 05 | | —02 | | —02 | | 39 | | 10 |

**Table 3** continued.

| Locality | q—p | Month J | F | M | A | M | J | J | A | S | O | N | D | Mean for the year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 1 | 46 | 27 | 40 | 62 | 35 | 80 | 85 | 66 | 48 | 56 | 68 | 53 | 56 |
| 62°02′N. | 2 | 57 | 17 | 45 | 75 | 12 | 47 | 77 | 69 | 62 | 52 | 61 | 10 | 49 |
| 6°45′W. | 3 | 29 | 51 | 22 | 25 | 16 | 50 | 59 | 56 | 22 | 38 | 11 | 23 | 34 |
| Thorshavn | 4 | 33 | 39 | 43 | 43 | 42 | 18 | 38 | 34 | 21 | 32 | —14 | 45 | 31 |
| | 5 | 12 | 18 | 56 | 50 | 27 | 25 | 45 | 10 | 11 | 20 | —15 | 45 | 25 |
| | 6 | 57 | 12 | 30 | 62 | 46 | 20 | 33 | 09 | —12 | —05 | —05 | 40 | 24 |
| | 7 | 38 | —15 | 22 | 50 | 14 | 39 | 41 | 33 | —18 | 05 | 48 | —04 | 20 |
| | 8 | 16 | 10 | —08 | 17 | 50 | 28 | —07 | 34 | 36 | —36 | 28 | 47 | 18 |
| | 9 | 14 | 18 | —21 | 18 | 47 | 18 | 13 | 21 | 24 | 21 | 18 | 50 | 20 |
| 19 | 1 | 34 | 56 | 49 | 31 | 26 | 61 | 70 | 72 | 78 | 41 | 82 | 77 | 56 |
| 64°48′N. | 2 | —14 | 02 | 14 | 62 | 30 | 34 | 23 | 53 | 36 | 25 | 18 | 44 | 27 |
| 10°33′E. | 3 | —33 | 08 | 49 | 21 | 19 | 47 | 14 | 50 | —05 | 26 | —21 | —30 | 12 |
| Nordøerne | 4 | —44 | 21 | —12 | —18 | 28 | —10 | 58 | 19 | —12 | 18 | 01 | —40 | 01 |
| | 5 | —02 | —43 | —39 | 30 | 31 | 05 | 52 | —10 | 01 | —03 | —27 | —70 | —06 |
| | 6 | —30 | —64 | —38 | —06 | 30 | 39 | 39 | 50 | —09 | —17 | —03 | —51 | —05 |
| 20 | 1 | 14 | 77 | 34 | 83 | 48 | 33 | 77 | 58 | 00 | 78 | 50 | 36 | 49 |
| 62°52′N. | 2 | —27 | 13 | 34 | 43 | 15 | —10 | 07 | 38 | —10 | —28 | 45 | 49 | 14 |
| 6°33′E. | 3 | —40 | 43 | 47 | 30 | —14 | —21 | 44 | —15 | —16 | 31 | 47 | —23 | 09 |
| Ona | 4 | —38 | 14 | 46 | 34 | 39 | —40 | —18 | 01 | —17 | 40 | 33 | —23 | 06 |
| | 5 | 39 | —15 | 10 | 45 | 30 | —50 | —02 | —25 | 33 | 34 | —36 | —28 | 03 |
| | 6 | 39 | 21 | —32 | 12 | 51 | 34 | —04 | 23 | 23 | 26 | —26 | —21 | 12 |
| 21 | 1 | 61 | 47 | 27 | 48 | 22 | 02 | 65 | 62 | 24 | 72 | 57 | 33 | 43 |
| 60°45′N. | 2 | —17 | 15 | 27 | 07 | —03 | 00 | 27 | 23 | —12 | 01 | 45 | 54 | 14 |
| 4°43′E. | 3 | —26 | —19 | 63 | 23 | 15 | 27 | 09 | 05 | —48 | 32 | 53 | 18 | 13 |
| Hellisø | 4 | —12 | —39 | 06 | 26 | 20 | 20 | 47 | —32 | —24 | —02 | 19 | 33 | 05 |
| | 5 | —06 | —51 | 18 | 11 | 00 | 29 | 26 | —27 | 14 | —13 | —09 | —08 | —01 |
| | 6 | —51 | —36 | 04 | 11 | 01 | —29 | 57 | 06 | —24 | 00 | —09 | —11 | —07 |
| 22 | 1 | —05 | 47 | 80 | 57 | 57 | 41 | 65 | 67 | 30 | 69 | 56 | 52 | 51 |
| 55°34·1′N. | 2 | —44 | —01 | 22 | 68 | 37 | 36 | 49 | 23 | 15 | 22 | 51 | 19 | 25 |
| 7°19·5′E. | 3 | —30 | —05 | 51 | 55 | 35 | 62 | 68 | —24 | —10 | 43 | 47 | —33 | 22 |
| Horns Rev | 4 | —11 | —31 | 07 | 68 | 27 | 01 | 59 | —10 | —51 | 30 | 32 | —11 | 09 |
| | 5 | 00 | —16 | 11 | —22 | 10 | 09 | 12 | —30 | 16 | 60 | —34 | —22 | 00 |
| | 6 | —25 | —27 | —06 | —28 | 25 | 30 | —16 | 22 | —06 | 54 | —42 | —04 | —02 |

some regularity in its variation. For a constant value of q—p an annual variation of $r_{pq}$ may be assumed. In the regions influenced by the polar front — the areas 9, 10, and 11 — the temperature conditions are less stable in the early part of the year than later on. The case is otherwise in the regions between the British Islands and Iceland, where the weather conditions in the autumn are unstable. A low degree of stability of the temperature conditions may be assumed to exhibit itself by low values of $r_{pq}$ for the same value of q—p and thus an annual variation of $r_{pq}$ may be accounted for. This question will be discussed in a future section (Section 5, p. 40).

The most striking regularity in the variation of $r_{pq}$ is its decrease with the increase of q—p. That means that the correlation of the monthly means is the less the farther off they are from one another. This could of course be imagined beforehand, but it is an interesting fact that the decrease of the correlation is to a considerable extent different for the different localities.

An investigation of the decrease of $r_{pq}$ with the increase of q—p may be untertaken by means of the mean values for the year given in Table 3. This procedure requires that the actual circumstances are compared with some stationary conditions which in reality are the object of the investigation.

In Form A three successive columns are considered. They may be the columns with the anomalies $x_{11}$, $x_{12}$, and $x_{13}$ at the top. Instead of the symbols used in Form A, the symbols stated in Form D are used in the following consideration. The number of groups of connected anomalies is designated by N. The number N is either 13 or 14, and in Form D is equal to 13. For the investigation of correlations between connected anomalies symbols and definitions from the textbook by Yule[1]) are used.

**Form D.**

$$\begin{array}{ccc} x_1' & x_2' & x_3' \\ x_1'' & x_2'' & x_3'' \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ x_1^{XIII} & x_2^{XIII} & x_3^{XIII} \end{array}$$

Referring to Form D we have:—

$$\Sigma x_1 = \Sigma x_2 = \Sigma x_3 = 0^{2})$$

[1]) G. U. Yule: An Introduction to the Theory of Statistics. (Second edition. London, 1912).

[2]) In fact, this and the following is exactly fulfilled for N=14 only (cf. footnote, p. 23).

The mean deviations of the zero order $\sigma_1$, $\sigma_2$, and $\sigma_3$ are determined by:—

$$\sigma_1^2 = \frac{1}{N}\Sigma x_1^2,\ \sigma_2^2 = \frac{1}{N}\Sigma x_2^2, \text{ and } \sigma_3^2 = \frac{1}{N}\Sigma x_3^2$$

The total correlations of zero order $r_{12}$, $r_{23}$, and $r_{13}$ are determined by:—

$$r_{12} = \frac{\Sigma x_1 x_2}{(\Sigma x_1^2 \cdot \Sigma x_2^2)^{1/2}} = \frac{\frac{1}{N}\Sigma x_1 x_2}{\sigma_1 \cdot \sigma_2},\quad r_{23} = \frac{\Sigma x_2 x_3}{(\Sigma x_2^2 \cdot \Sigma x_3^2)^{1/2}} = \frac{\frac{1}{N}\Sigma x_2 x_3}{\sigma_2 \cdot \sigma_3};$$

$$r_{13} = \frac{\Sigma x_1 x_3}{(\Sigma x_1^2 \cdot \Sigma x_3^2)^{1/2}} = \frac{\frac{1}{N}\Sigma x_1 x_3}{\sigma_1 \cdot \sigma_3}$$

The partial correlation $r_{13.2}$ of the first order may be taken as the expression for the correlation between the $x_1$- and the $x_3$-values if the $x_2$-values were all equal to zero, i. e., if the monthly means used for the calculation of the anomalies $x_2$ were all equal. The partial correlation $r_{13.2}$ may be found in the following way.

By means of the regression-equations

$$x_1 \sim b_{12}x_2 \text{ and } x_3 \sim b_{32}x_2$$

the regression-coefficients $b_{12}$ and $b_{32}$ are found from

$$b_{12} = \frac{\Sigma x_1 x_2}{\Sigma x_2^2} = r_{12} \cdot \frac{\sigma_1}{\sigma_2} \text{ and } b_{32} = \frac{\Sigma x_2 x_3}{\Sigma x_2^2} = r_{23} \cdot \frac{\sigma_3}{\sigma_2}$$

The mean deviations $\sigma_{1.2}$ and $\sigma_{3.2}$ of the first order are defined by

$$\sigma_{1.2}^2 = \frac{1}{N}\Sigma(x_1 - b_{12}x_2)^2 \text{ and } \sigma_{3.2}^2 = \frac{1}{N}\Sigma(x_3 - b_{32}x_2)^2$$

By means of the above expressions for $b_{12}$ and $b_{32}$ we obtain

$$\sigma_{1.2}^2 = \sigma_1^2(1 - r_{12}^2) \text{ and } \sigma_{3.2}^2 = \sigma_3^2(1 - r_{23}^2)$$

The deviations $x_1 - b_{12}x_2$ and $x_3 - b_{32}x_2$ may be taken as the values that should have been found for $x_1$ and $x_3$ if the monthly means used for the calculation of the anomalies $x_2$ were all equal. Thus the partial correlation $r_{13.2}$ may be written as

$$r_{13.2} = \frac{\Sigma(x_1 - b_{12}x_2)(x_3 - b_{32}x_2)}{[\Sigma(x_1 - b_{12}x_2)^2 \cdot \Sigma(x_3 - b_{32}x_2)^2]^{1/2}}$$

By means of the expressions developed above we obtain

$$r_{13.2} = \frac{r_{13} - r_{12} \cdot r_{23}}{\sqrt{1 - r_{12}^2} \cdot \sqrt{1 - r_{23}^2}}$$

Under stationary conditions the values of $r_{12}$ and $r_{23}$ may be replaced by a common value r represented by the mean value of the correlations for successive months. If, further, the anomalies accounting for the correlations $r_{12}$, $r_{23}$, and $r_{13}$ are effaced in a short time, less than a month, the partial correlation $r_{13.2}$ may be put equal to zero. In this case we get $r_{13} = r^2$. Under these conditions a general expression for an arbitrary correlation $r_{pq}$ valid for the interval q—p months is $r_{pq} = r^{q-p}$.

This case relates to an extreme condition. Another extreme may occur when the effacement of an anomaly is very — infinitely — slow. Then an arbitrary correlation $r_{pq}$ valid for the interval q—p months may be equal to the normal value r of the correlation for successive months.

A general formula for $r_{pq}$ embracing the extreme cases considered may be given as:

$$r_{pq} = r^{[(q-p)^E]}$$

where E is a characteristic constant that may be taken as a measure of the effacement of the anomalies. For $E = 1$ we have $r_{pq} = r^{q-p}$ and for $E = 0$ we get $r_{pq} = r$. In the following E is termed the "effacement constant" or simply the "effacement". The expression for $r_{pq}$ is not based on any other considerations than those stated above and for values of E between 0 and 1 empirical justification for the expression must be sought.

According to what has been explained it seems reasonable to use $r^{[(q-p)^E]}$ as an approximate expression for the values of $r_{pq}$, but it must be emphasized that the expression is only approximate. In Table 3 some negative values for $r_{pq}$ are found also in the means for the year. These may be accidental but the possibility exists that they are real and that the effacement of an anomaly may take place in such a way that a positive anomaly is normally followed by a negative anomaly and *vice-versa*. Thus it is to be remarked that the above expression for $r_{pq}$ can be used for positive values only.

To what degree the expression for $r_{pq}$ for a suitable value of E is in accordance with the real variation of $r_{pq}$ may be illustrated by two examples. In Table 4 are recorded the values for $r_{pq}$ obtained as means for the year from Table 3 for Areas 10 — 15. Means are computed for groups of the areas, viz., for the areas 10 and 11 and for the areas 12, 13, 14, and 15. For comparison with these means the values of $r_{pq} = r^{[(q-p)^E]}$ are calculated for $r = 0{\cdot}44$ and $E = 0{\cdot}80$, and for $r = 0{\cdot}47$ and $E = 0{\cdot}41$ respectively. The calculated values are given in the table. The comparison is shown graphically in Figures 2 and 3, where the actual means are given by the dots and calculated values of $r_{pq}$ by the curves. It is seen that the calculated values for $r_{pq}$ are in quite good accord with the actual means and that the difference in the effacement of the anomalies for the two groups of areas are characterized by the values of the effacement constant E.

**Table 4.**

| Area | q—p 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0·38 | 0·20 | 0·08 | 0·04 | —0·03 | 0·04 | | | |
| 11 | 0·51 | 0·28 | 0·15 | 0·14 | 0·11 | 0·04 | | | |
| Means for Areas 10 and 11 | 0·44 | 0·24 | 0·12 | 0·09 | 0·04 | 0·04 | | | |
| $r_{pq} = 0{\cdot}44^{[(q-p)^{0.80}]}$ | 0·44 | 0·24 | 0·13 | 0·08 | 0·05 | 0·03 | | | |
| 12 | 0·53 | 0·42 | 0·35 | 0·21 | 0·23 | 0·24 | 0·28 | 0·25 | 0·31 |
| 13 | 0·60 | 0·47 | 0·34 | 0·28 | 0·30 | 0·23 | 0·19 | 0·17 | 0·11 |
| 14 | 0·42 | 0·33 | 0·33 | 0·29 | 0·25 | 0·25 | 0·15 | 0·25 | 0·32 |
| 15 | 0·33 | 0·27 | 0·21 | 0·12 | 0·17 | 0·17 | 0·12 | 0·20 | 0·22 |
| Means for Areas 12, 13, 14, and 15 | 0·47 | 0·37 | 0·31 | 0·22 | 0·24 | 0·22 | 0·18 | 0·22 | 0·24 |
| $r_{pq} = 0{\cdot}47^{[(q-p)^{0.41}]}$ | 0·47 | 0·37 | 0·31 | 0·27 | 0·23 | 0·22 | 0·19 | 0·17 | 0·16 |

Incidentally the actual mean values 0·44 and 0·47 for r in the two cases are about the same, and it is accidental that these mean values are found to be the most suitable for insertion in the expression $r_{pq} = r^{[(q-p)^E]}$. In order to obtain the best possible agreement between the actual and the calculated values of $r_{pq}$ the most suitable values should be chosen for both r and E. For this purpose a graphical process has been used, which is illustrated by Figure 4.

The coordinate system in the figure has its zero-point at O, the axis of abscissae OP, and the axis of ordinates OQ. The inserted scales — the (q—p)-scale and the $r_{pq}$-scale — hold for the axis of abscissae and the axis of ordinates respectively. With the unit of length OP the (q—p)-scale has divisions for log (q—p) equal to 0·000, 0·301, 0·477, 0·602, . . . , i. e., for (q—p) equal to 1, 2, 3, 4, . . . The divisions are marked with the last figures. With the same unit of length the $r_{pq}$-scale has its principal divisions for —log (—log $r_{pq}$) equal to 0·000, 0·156, 0·282, 0·400, . . . , i. e., for $r_{pq}$ equal to 0·1, 0·2, 0·3, 0·4, . . .

The actual means for $r_{pq}$ for Areas 10 and 11 and for Areas 12, 13, 14, and 15 as found in Table 4 are plotted in the figure according to the scales for q—p and $r_{pq}$. If the expression $r_{pq} = r^{[(q-p)^E]}$ with suitably chosen values of r and E should be in complete agreement with the actual means for $r_{pq}$ the dots representing these values in the figure should lie on straight lines. This is approximately the case, and the lines $L_1$ and $L_2$ are drawn freehand to follow the plotted values in the best way. When the lines $L_1$ and $L_2$ are drawn, the values of r and E may be determined. Their points of intersection with the axis of ordinates give the values of r. These values are 0·44 and 0·47. The values of E may be read off by the arrangement shown in the upper part of the figure. Through the point A on the ordinate axis the line AB is drawn parallel to the axis of abscissae, intersecting the line PB

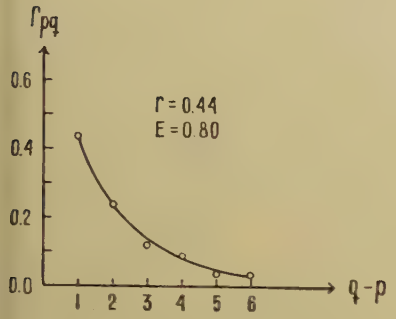


Fig. 2. Curve showing the variation of $r_{pq}$ with q—p for Areas 10 and 11. The dots indicate actual mean values for the two areas (see Table 4).

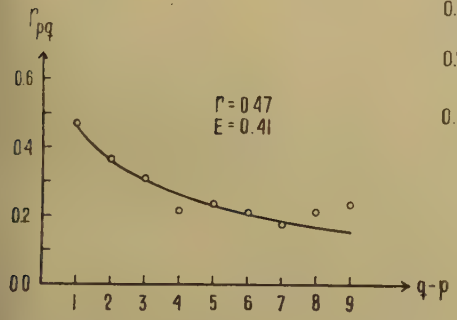


Fig. 3. Curve showing the variation of $r_{pq}$ with q—p for Areas 12,13,14, and 15. The dots indicate actual mean values for these areas (see Table 4).

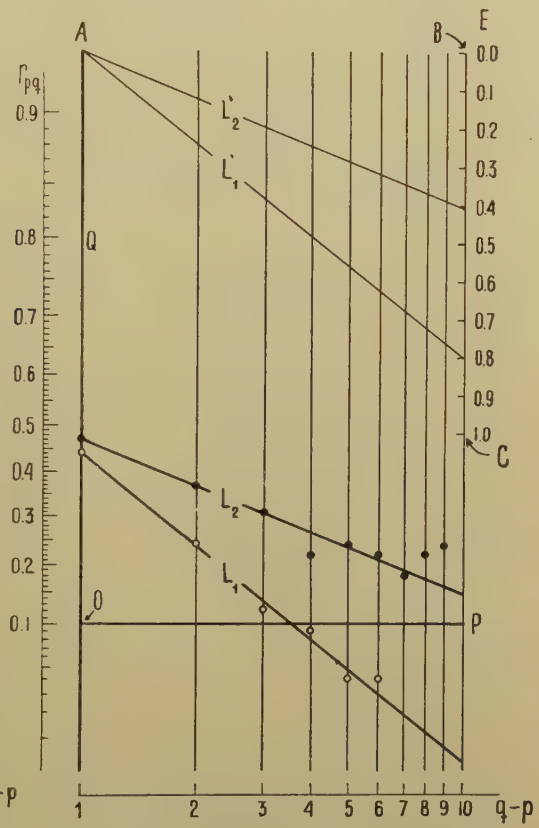


Fig. 4. Diagram for determining the "effacement" constant E. The outline circles relate to Areas 10 and 11, the full circles to Areas 12, 13, 14, and 15 (see Table 4).

parallel to the axis of ordinates in B. The distance from B to the point C on the line PB is equal to the unit of length OP. The distance BC is divided into ten equal parts and forms a scale for E with the divisions 0·0, 0·1, . . . When the lines $L'_1$ and $L'_2$ are drawn through the point A parallel to the lines $L_1$ and $L_2$ their intersections with the E-scale give the values of E. These values are 0·80 and 0·41.

The curves in Figures 2 and 3 are based on diagram Figure 4. The ordinates of the curves in Figures 2 and 3 for q—p equal to 1, 2, 3, . . . are found by reading off on the $r_{pq}$-scale in Figure 4 the lengths of the ordinates of the lines $L_1$ and $L_2$ for the same values 1, 2, 3, . . . of q—p.

## 4. Dependence of the Effacement Constant on Locality.

As in the preceding section, we shall disregard the seasonal variation of $r_{pq}$ and take the yearly mean values recorded in Table 3 as valid for certain stationary conditions. By the process given in detail above the characteristic constants r and E for each of the areas considered can be found from the yearly mean values $r_1$, $r_2$, ... The values found are recorded in Table 5 and are also indicated in Figure 5. The column headed f in Table 5 is explained below (p. 43).

**Table 5.**

| Locality | r | E | f | Locality | r | E | f |
|---|---|---|---|---|---|---|---|
| 1 | 0·44 | 0·90 | 1·5 | 12 | 0·54 | 0·53 | 1·0 |
| 2 | ·58 | ·89 | 1·1 | 13 | ·61 | ·64 | 1·0 |
| 3 | ·71 | ·49 | 1·0 | 14 | ·42 | ·28 | 1·0 |
| 4 | ·31 | ·32 | 1·0 | 15 | ·34 | ·35 | 1·0 |
| 5 | ·31 | ·22 | 1·0 | 16 | ·52 | ·87 | 1·2 |
| 6 | ·26 | ·67 | 1·5 | 17 | ·40 | ·67 | 1·2 |
| 7 | ·40 | ·61 | 1·1 | 18 | ·58 | ·56 | 1·0 |
| 8 | ·25 | ·40 | 1·2 | 19 | ·56 | (1·25) | — |
| 9 | ·43 | ·74 | 1·2 | 20 | ·46 | 0·93 | 1·5 |
| 10 | ·40 | ·90 | 1·6 | 21 | ·43 | ·93 | 1·6 |
| 11 | ·50 | ·82 | 1·2 | 22 | ·51 | ·88 | 1·3 |

Figure 6 gives for each of the areas considered a graphical representation of the yearly means $r_1$, $r_2$, $r_3$, ... and of the curve $r_{pq} = r^{[(q-p)^E]}$. Each part-figure is analogous to Figures 2 and 3.

An inspection of Figure 5 shows that the effacement constant E varies more or less regularly with place. As was seen already in Figures 2 and 3, E is large for Areas 10 and 11 which are influenced by the polar front, whereas it is essentially smaller for Areas 12, 13, 14, and 15 which lie to the south and southwest of Iceland. In the latter areas the temperature anomalies of the Atlantic Current appear fairly clearly, and as these anomalies are of long duration one gets low values of E. The same applies to Station 18 (Thorshavn, in the Faroe Islands). On the other hand, the effacement constant attains high values for Area 16 north of Scotland, for Stations 19, 20, and 21 off the Norwegian coast, and for Station 22 in the eastern part of the North Sea. For coastal waters the meteorological conditions are probably the decisive factors in the temperature anomalies.

In this connection we may examine the variation of surface salinity which may be supposed to be influenced mainly by the currents, whereas surface temperature is probably highly dependent on the air temperature. Suitable data are at hand for Station 22, "Horns Rev" lightvessel. From monthly means of surface salinity for the years 1900—1913, published in the Danish Nautical-Meteorological Annals, we have computed correlation coefficients for salinity in the same way as was done for temperature. The results are given in Table 6.

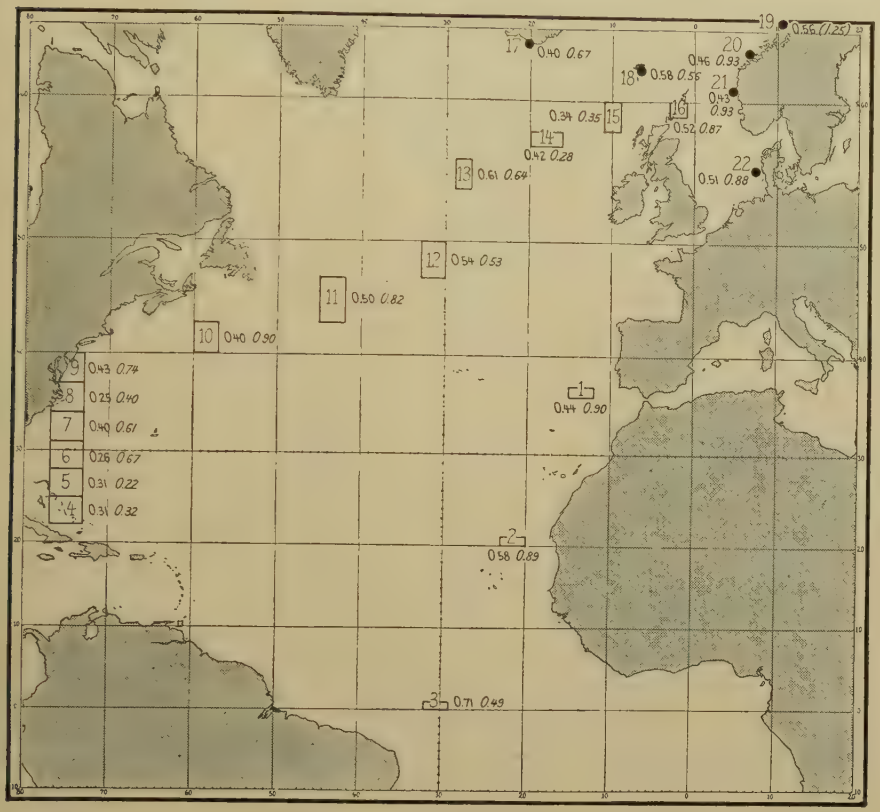


Fig. 5.
Chart showing values of the constants r (figures sloping to the left) and E (figures sloping to the right) for the various areas and stations.

As was done for surface temperature, for the surface salinity we use $r^{[(q-p)^E]}$ as an approximate expression for the variation of $r_{pq}$ with q—p. Proceeding as explained for the temperature, we obtain the following values: r = 0·54, E = 0·66. With these constants the variation of $r_{pq}$ will be as shown by the curve in Figure 7 in which the dots indicate the actual yearly means.

A comparison with the constants found for surface temperature at the same station (r = 0·51, E = 0·88) shows that while the values of r are practically identical, the value of E for salinity is essentially smaller than that for temperature. Thus — as was to be expected — the effacement of a salinity anomaly is slower than the effacement of a temperature anomaly.

For the same locality (22, "Horns Rev" lightvessel) we have also computed correlation coefficients for air temperature as was done for surface temperature and salinity. The material used is the monthly

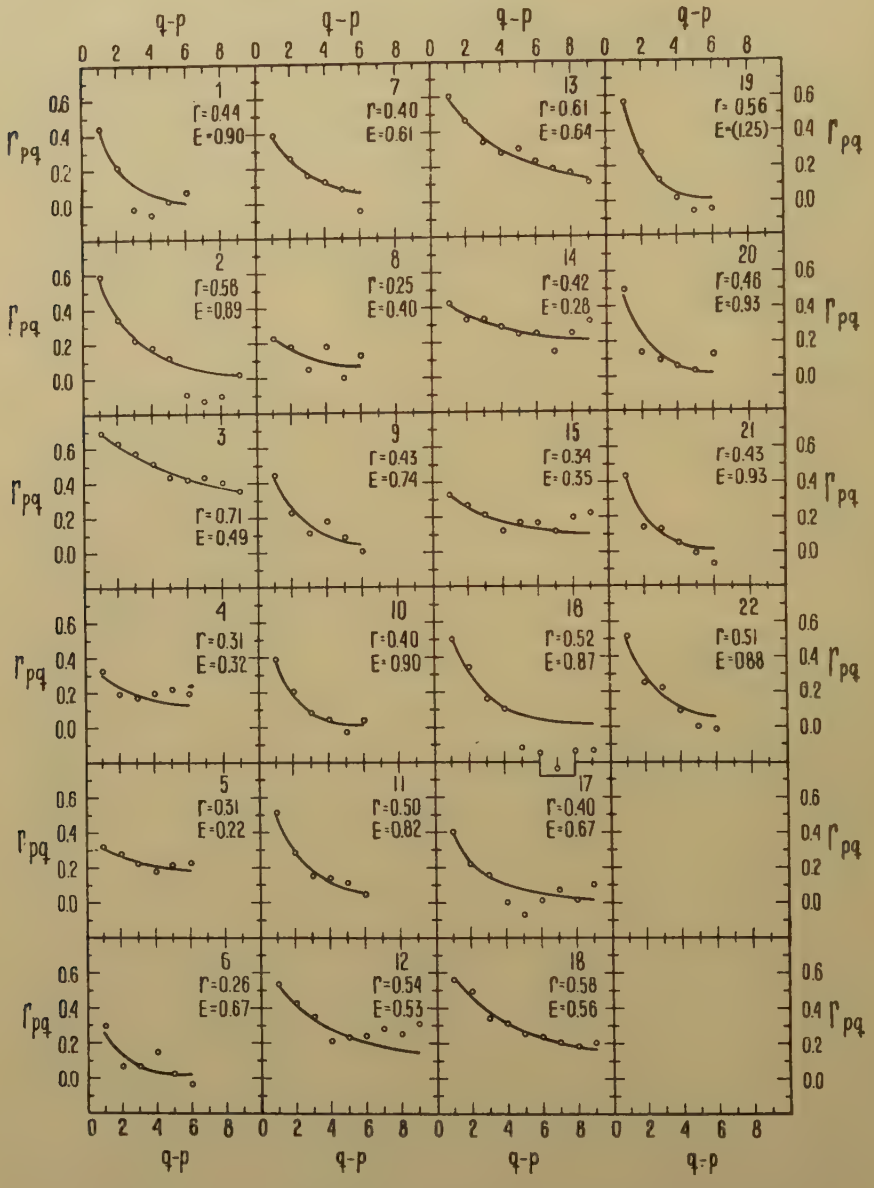


Fig. 6. Curves showing the variation of $r_{pq}$ with q—p for surface temperature at localities 1—22. The dots indicate actual values.

means of air temperature at 8 a. m. during the years 1900—1913, published in the Danish Nautical-Meteorological Annals. The correlations found are given in Table 7.

From an approximation to the curve $r_{pq} = r^{[(q-p)E]}$ we find the

## Table 6. Values of $100 \cdot r_{pq}$ for Surface Salinity.

| Locality | q—p | Month J | F | M | A | M | J | J | A | S | O | N | D | Mean for the year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55°34·1′N. | 1 | 77 | 65 | 26 | 37 | 85 | 57 | 55 | 59 | 20 | 34 | 40 | 85 | 53 |
| | 2 | 48 | 54 | 17 | 69 | 28 | 52 | 40 | 48 | 14 | 24 | 33 | 32 | 38 |
| 7°19·5′E. | 3 | 29 | 41 | 51 | 55 | 40 | 48 | 10 | —07 | 18 | 09 | 20 | 24 | 28 |
| | 4 | —25 | 31 | 52 | 41 | 37 | 17 | 27 | 52 | 13 | 22 | —02 | 00 | 22 |
| "Horns Rev" | 5 | —01 | 27 | 61 | 23 | 21 | —31 | 56 | 24 | —16 | 29 | —24 | 02 | 14 |
| | 6 | —30 | —31 | 39 | 29 | 34 | 32 | —05 | 44 | 03 | —05 | —04 | —35 | 06 |

## Table 7. Values of $100 \cdot r_{pq}$ for Air Temperature.

| Locality | q—p | Month J | F | M | A | M | J | J | A | S | O | N | D | Mean for the year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55°34·1′N. | 1 | 16 | 42 | 48 | 39 | 56 | 55 | 70 | 69 | 24 | 45 | 20 | —26 | 38 |
| | 2 | —12 | —19 | 08 | 41 | 13 | 45 | 51 | 12 | —13 | 71 | —10 | —12 | 15 |
| 7°19·5′E. | 3 | 15 | —39 | 65 | 41 | 33 | 76 | 34 | —42 | 17 | 18 | 25 | —55 | 16 |
| | 4 | —07 | 20 | —06 | 46 | 20 | 16 | 67 | —63 | —18 | 41 | 08 | —13 | 09 |
| "Horns Rev" | 5 | —05 | 23 | 18 | —05 | —05 | 06 | —07 | —33 | 43 | —02 | —65 | —26 | —05 |
| | 6 | —19 | —50 | 31 | —58 | 20 | —11 | 10 | 25 | 09 | 12 | —64 | —12 | —09 |

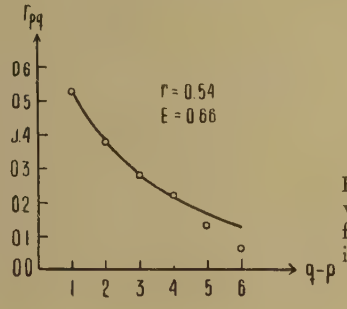


Fig. 7. Curve showing the variation of $r_{pq}$ with q—p for surface salinity at locality 22. The dots indicate actual values.

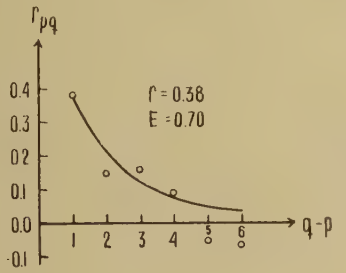


Fig. 8. Curve showing the variation of $r_{pq}$ with q—p for air temperature at locality 22. The dots indicate actual values.

**Form E.**

| q p | Jan. | Feb. | Mar. | Apr. | May | June |
|---|---|---|---|---|---|---|
| | | | Month | | | |
| 1 | $\frac{r_{12\,13}+r_{12}}{2}$ | $\frac{r_{12}+r_{23}}{2}$ | $\frac{r_{23}+r_{34}}{2}$ | $\frac{r_{34}+r_{45}}{2}$ | $\frac{r_{45}+r_{56}}{2}$ | $\frac{r_{56}+r_{67}}{2}$ |
| 2 | $\frac{r_{11\,13}+r_{13}}{2}$ | $\frac{r_{12\,14}+r_{24}}{2}$ | $\frac{r_{13}+r_{35}}{2}$ | $\frac{r_{24}+r_{46}}{2}$ | $\frac{r_{35}+r_{57}}{2}$ | $\frac{r_{46}+r_{68}}{2}$ |
| 3 | $\frac{r_{10\,13}+r_{14}}{2}$ | $\frac{r_{11\,14}+r_{25}}{2}$ | $\frac{r_{12\,15}+r_{36}}{2}$ | $\frac{r_{14}+r_{47}}{2}$ | $\frac{r_{25}+r_{58}}{2}$ | $\frac{r_{36}+r_{69}}{2}$ |
| 4 | $\frac{r_{9\,13}+r_{15}}{2}$ | $\frac{r_{10\,14}+r_{26}}{2}$ | $\frac{r_{11\,15}+r_{37}}{2}$ | $\frac{r_{12\,16}+r_{48}}{2}$ | $\frac{r_{15}+r_{59}}{2}$ | $\frac{r_{26}+r_{6\,10}}{2}$ |
| 5 | $\frac{r_{8\,13}+r_{16}}{2}$ | $\frac{r_{9\,14}+r_{27}}{2}$ | $\frac{r_{10\,15}+r_{38}}{2}$ | $\frac{r_{11\,16}+r_{49}}{2}$ | $\frac{r_{12\,17}+r_{5\,10}}{2}$ | $\frac{r_{16}+r_{6\,11}}{2}$ |
| 6 | $\frac{r_{7\,13}+r_{17}}{2}$ | $\frac{r_{8\,14}+r_{28}}{2}$ | $\frac{r_{9\,15}+r_{39}}{2}$ | $\frac{r_{10\,16}+r_{4\,10}}{2}$ | $\frac{r_{11\,17}+r_{5\,11}}{2}$ | $\frac{r_{12\,18}+r_{6\,12}}{2}$ |
| Mean | $m_1$ | $m_2$ | $m_3$ | $m_4$ | $m_5$ | $m_6$ |

constants $r = 0{\cdot}38$, $E = 0{\cdot}70$. Figure 8 gives the curve $r_{pq} = r^{[(q-p)^E]}$ for these values of r and E while the dots indicate the actual values of $r_{pq}$. The value of E suggests that the anomalies of air temperature are of longer duration than the anomalies of surface water temperature. As regards the air temperature, it should be emphasized, however, that the irregular variation with q—p of the yearly means of $r_{pq}$ involves much uncertainty in the estimate of E.

## 5. Seasonal Variation of the Correlation Coefficients.

It was mentioned above that the great dispersion of the $r_{pq}$-values springs naturally from the fact that the number of pairs of values on which they are based is rather small (13 or 14). Moreover, it was explained that if anomalies for months of the same name differ exceptionally from anomalies in the preceding and the subsequent months, a series of correlations situated along sloping lines in a table of $r_{pq}$ will differ in an exceptional way from the neighbouring correlations in the table. Such exceptional correlation values will influence the yearly mean values $r_1$, $r_2$, $r_3$, ..., but do not prevent these values from varying evenly with q—p. On the other hand, the exceptional values may cause the variation of $r_{pq}$ for a fixed value of q—p to become irregular to such a degree that it is impossible to judge whether a regular seasonal variation is present or not. In an examination of the seasonal variation of the correlation coefficients one must therefore set off possible variation by taking averages.

| July | Aug. | Sept. | Oct. | Nov. | Dec. | Mean for the year |
|---|---|---|---|---|---|---|
| Month | | | | | | |
| $\frac{r_{67}+r_{78}}{2}$ | $\frac{r_{78}+r_{89}}{2}$ | $\frac{r_{89}+r_{9\,10}}{2}$ | $\frac{r_{9\,10}+r_{10\,11}}{2}$ | $\frac{r_{10\,11}+r_{11\,12}}{2}$ | $\frac{r_{11\,12}+r_{12\,13}}{2}$ | $r_1$ |
| $\frac{r_{57}+r_{79}}{2}$ | $\frac{r_{68}+r_{8\,10}}{2}$ | $\frac{r_{79}+r_{9\,11}}{2}$ | $\frac{r_{8\,10}+r_{10\,12}}{2}$ | $\frac{r_{9\,11}+r_{11\,13}}{2}$ | $\frac{r_{10\,12}+r_{12\,14}}{2}$ | $r_2$ |
| $\frac{r_{47}+r_{7\,10}}{2}$ | $\frac{r_{58}+r_{8\,11}}{2}$ | $\frac{r_{69}+r_{9\,12}}{2}$ | $\frac{r_{7\,10}+r_{10\,13}}{2}$ | $\frac{r_{8\,11}+r_{11\,14}}{2}$ | $\frac{r_{9\,12}+r_{12\,15}}{2}$ | $r_3$ |
| $\frac{r_{37}+r_{7\,11}}{2}$ | $\frac{r_{48}+r_{8\,12}}{2}$ | $\frac{r_{59}+r_{9\,13}}{2}$ | $\frac{r_{6\,10}+r_{10\,14}}{2}$ | $\frac{r_{7\,11}+r_{11\,15}}{2}$ | $\frac{r_{8\,12}+r_{12\,16}}{2}$ | $r_4$ |
| $\frac{r_{27}+r_{7\,12}}{2}$ | $\frac{r_{38}+r_{8\,13}}{2}$ | $\frac{r_{49}+r_{9\,14}}{2}$ | $\frac{r_{5\,10}+r_{10\,15}}{2}$ | $\frac{r_{6\,11}+r_{11\,16}}{2}$ | $\frac{r_{7\,12}+r_{12\,17}}{2}$ | $r_5$ |
| $\frac{r_{17}+r_{7\,13}}{2}$ | $\frac{r_{28}+r_{8\,14}}{2}$ | $\frac{r_{39}+r_{9\,15}}{2}$ | $\frac{r_{4\,10}+r_{10\,16}}{2}$ | $\frac{r_{5\,11}+r_{11\,17}}{2}$ | $\frac{r_{6\,12}+r_{12\,18}}{2}$ | $r_6$ |
| $m_7$ | $m_8$ | $m_9$ | $m_{10}$ | $m_{11}$ | $m_{12}$ | |

Form E is derived in an easily comprehensible way from Form C by averaging. On the right-hand side of both forms are recorded the mean values $r_1, r_2, \ldots r_6$ which are identical in the two forms.

In the case of some of the correlations $r_{pq}$ used in obtaining averages, $q \leq 12$, while for the others $q > 12$. As explained above the former were computed from 14 pairs of values, the latter from 13 pairs only. Of the mean values recorded under January in Form E, $r_{12\,13}$, $r_{11\,13}$, .. .. $r_{7\,13}$ have thus been computed on the basis of the January anomalies for the years 1901—1913 while $r_{12}$, $r_{13}$, .... $r_{17}$ were computed from the January anomalies for the years 1900—1913. Disregarding this difference we may say that the mean values in the January column are computed from correlations between the January anomalies and the anomalies for all the other months of the year. Among these, however, the anomalies for July are used twice, in both $r_{7\,13}$ and $r_{17}$, either of which occurs for $q-p=6$. Analogous considerations hold for the other months in Form E.

The mean values $m_1, m_2, \ldots m_{12}$ for each month are recorded at the foot of form E. These mean values are computed from the mean values given in the various columns. In taking these averages the last mean value — for $q-p = 6$ — is given the weight 0·5 while the other mean values are given the weight 1. For instance one has thus

$$m_1 = \frac{r_{12}+r_{13}+r_{14}+r_{15}+r_{16}+\frac{r_{17}+r_{7\,13}}{2}+r_{8\,13}+r_{9\,13}+r_{10\,13}+r_{11\,13}+r_{12\,13}}{11}$$

As explained above, $r_{17}$ may be taken as equal to $r_{7\,13}$ and consequently $\frac{r_{17} + r_{7\,13}}{2}$ might be replaced by $r_{17}$. The January anomalies therefore occur 11 times and the anomalies for each of the other months once in the expression for $m_1$. Analogous conditions apply to the other months.

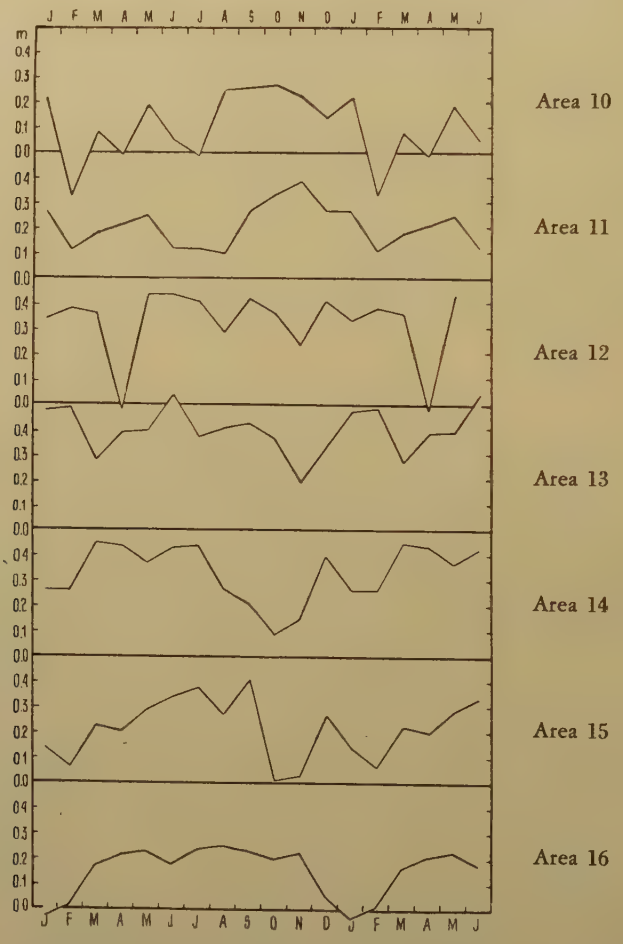


Fig. 9. Seasonal variation of the correlation coefficients for surface temperature at Localities 10—16. For method of computation of the plotted means m, see text.

The seasonal variation of the mean values m found from Form E is given in Figure 9 for some of the areas considered (10—16).

If it is supposed that at a certain time of the year a disturbance of otherwise stationary conditions in the anomalies normally occurs, this

must be expected to become apparent in a typical variation of the mean values $m_1, m_2, \ldots$ That the variation is typical may appear either from it being homogeneous for several neighbouring areas or from it being in accordance with the hydrographical and meteorological conditions in the area considered. A false form of the variations in the m-values may arise if the observations in several areas have been taken by the same ships at short intervals of time. A variation that cannot be brought into accord with known hydrographical or meteorological conditions should therefore be submitted to a closer examination before it can be regarded as real.

The significance of the mean values $m_1, m_2, \ldots$ under stationary conditions may to some degree be elucidated by the following consideration. In Section 3 it has been explained that under stationary conditions it may be reckoned that $r_{pq} = r^{[(q-p)^E]}$ where r indicates a smoothed value for the correlation between the anomalies of two neighbouring months and where E is the characteristic termed the effacement constant. From the expression $r_{pq} = r^{[(q-p)^E]}$ values can be found that are analogous to the correlations in the expression for $m_1$. A mean value M analogous to $m_1, m_2, \ldots$ can be computed from the formula:—

$$M = \frac{2r + 2r^{(2^E)} + 2r^{(3^E)} + 2r^{(4^E)} + 2r^{(5^E)} + r^{(6^E)}}{11}$$

In many cases the value of M does not differ much from the value of $r^{(3^E)}$. This is to say that when $r_{pq}$ can be given by $r_{pq} = r^{[(q-p)^E]}$ a mean value m can in many cases be reckoned as equal to the correlation for an interval of 3 months.

Table 8 gives the ratio $f = \frac{M}{r^{(3^E)}}$ for various values of r and E. From this table are taken the values of f recorded in Table 5.

**Table 8.**

**Values of $f = \frac{M}{r^{(3^E)}}$ for various Values of r and E.**

| r \ E | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 | 0·6 | 0·7 | 0·8 | 0·9 | 1·0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0·1 | 1·0 | 1·1 | 1·2 | 1·4 | 1·7 | 2·3 | 3·5 | 5·7 | 10·2 | 20·2 |
| 0·2 | 1·0 | 1·0 | 1·1 | 1·2 | 1·3 | 1·5 | 1·9 | 2·6 | 3·7 | 5·7 |
| 0·3 | 1·0 | 1·0 | 1·0 | 1·1 | 1·2 | 1·3 | 1·4 | 1·7 | 2·2 | 2·9 |
| 0·4 | 1·0 | 1·0 | 1·0 | 1·1 | 1·1 | 1·1 | 1·2 | 1·4 | 1·6 | 1·9 |
| 0·5 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·1 | 1·1 | 1·2 | 1·3 | 1·4 |
| 0·6 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·1 | 1·1 | 1·1 | 1·2 |
| 0·7 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·1 |
| 0·8 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 |
| 0·9 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 |

# Methods for Rapid Temperature Determination from Thermograms along a Ship's Course.

By

**E. Theisen.**

AS is well known, Messrs. Negretti & Zambra, of London, manufacture sea-thermographs which give very accurate records of the temperatures of the cooling-water in motor and steamships. If the bulb of the sea-thermograph is placed so that the cooling-water passes it just after being pumped in through the ship's side, the sea-thermograph will register the temperature of the sea outside the ship at the depth of the cooling-water inlet. The same firm has also constructed another type of this instrument. In this type the bulb is

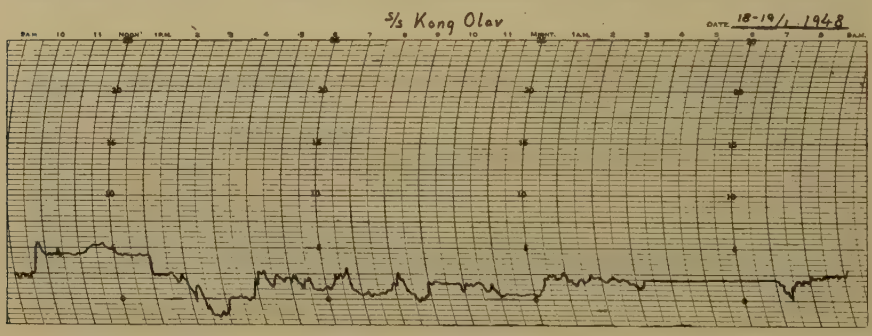


Figure 1. Thermogram

placed in a recess in the keel and the sea-temperature under the keel is registered. In both types of instrument the temperature is recorded on a chart as a function of time — shown in Figure 1 — with time as abscissa (positive direction towards the right) and temperature as ordinate (positive direction upwards). The abscissae are straight whereas the ordinates are curved. An ordinate is marked for every thirty minutes.

From sea-thermographs installed onboard liners which pass regularly through a fixed position at sea, a good collection of data may be obtained for the study of variations in temperature at the depth of the

cooling-water inlet (or the depth of the keel) at this particular position (see:— J. E g g v i n: "The Movements of a Cold Water Front". Rep. Norw. Fish. and Mar. Invest., Vol. VI, No. 5).

It is, however, a lengthy task to read the sea-temperatures at these fixed positions from the thermograms, as it is not as a rule known when the ship passed through these points but only where the ship was at other definite times. For the purpose of determining quickly and as accurately as possible the time when the ship was at the chosen position, four instruments have been constructed, which may be called "Timedivider", "Timedivider S.", "Timedivider Compasses" I and II.

**The Timedivider.**

This instrument is used to find temperature when the fixed position lies on the route of liners between two ports so near each other that only departure from and arrival in port are recorded, and intermediate positions of the ships are not stated.

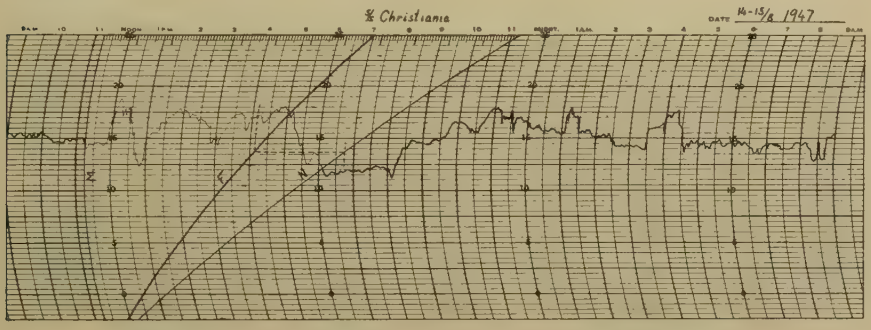


Figure 2. The Timedivider placed on a Thermogramchart.

When the ships always follow the same route between the harbours M and N and pass through the fixed point F, the relation between the distance from M to F (MF) and the distance from F to N (FN) will be constant. If we suppose that each vessel runs at a constant speed throughout the passage, it is simple enough, but needs much work, to reckon how much time it takes to travel from M to F. By adding this time to the time of departure from M, the time will be found when the vessel was at the fixed position (F).

To carry out this work easily the Timedivider may be used. This instrument is made of a sheet of transparent celluloid and is shown in Figure 2 placed on a thermogram.

It is trapezoidal in form and the two straight parallel sides have the same distance from each other as the distance between the highest and lowest temperatures on the thermogramchart. The upper side must have at least a length corresponding to the time taken by the slowest vessel between the harbours, on the same scale as the chart. The lower side can at most have a length corresponding to the time taken by the fastest vessel between the harbours, on the same scale as the chart. The

left side has the same curve as the ordinates. If the distance from the left side to the right side, parallel to the upper and the lower side, is termed $s$, and the left side is divided in degrees Centigrade ($\vartheta$) in the same manner as the ordinates on the thermogramchart, then it will be convenient to make the length of the left side such that $\frac{ds}{d\vartheta} = \frac{s_2 - s_1}{\vartheta_1}$ where $s_2$ and $s_1$ are the lengths of the upper and lower sides respectively, and $\vartheta_1$ is the temperature range covered by the thermogramchart.

Across the Timedivider there is a curve which divides the length $s$ in the proportion MF : FN.

On the left-hand side is indicated the name of the harbour from which the ships come (M) and on the right, its destination (N).

The upper side is graduated for every 5 minutes on the same scale as on the abscissae of the thermogram.

If a temperature record has been obtained between M and N and the temperature at a fixed point F is required, the Timedivider is placed on the chart so that its upper side falls along the upper abscissa and the left side (marked M) falls on the time of departure from M (11.15 a. m. on Fig. 2). Then the ordinate must be found which corresponds to the time of arrival at N (6.45 p. m. on Fig. 2). From the intersection of this ordinate with the right-hand side of the Timedivider (marked N) the same abscissa is followed towards the left (dotted on Fig. 2) as far as to the curve on the Timedivider. As the Timedivider is transparent, we can see the ordinate on the thermogram on which this point lies. This ordinate gives the time when the ship was at F, and the temperature recorded at this ordinate is consequently the temperature at F.

As thermogramcharts are changed once in 24 hours on the sea-thermograph the time of departure from M and the time of arrival at N are not always found on the same chart. In this case the scale at the top of the Timedivider must be used, the Timedivider being placed by means of the scale so that the left side falls at the right distance before the time at which the thermogram starts.

The scale is also useful for placing the Timedivider in position on the thermogramchart, as it is divided for 5 minute intervals, whereas the chart is divided only for each half hour.

**The Timedivider S.**

When the course of a ship covers a fairly long stretch of sea, the ship's position is determined from time to time and can be marked on a chart. Between two positions, M and N, lies the fixed point F at where we wish to know the temperature. The relation $\frac{MF}{FN}$ will vary from voyage to voyage.

The Timedivider may be constructed in such a way that it is suitable for finding the temperature at F in this case also. This type of Timedivider may be called Timedivider S. It has the same form as the Timedivider and is also made of transparent celluloid but contains more

lines. At a distance from one another of about 0·5 cm. straight lines are drawn parallel to the parallel straight sides. A close series of curves is also drawn, each of them dividing all the lengths $s$ in one and the same relation. The curves may be drawn in different colours and numbered, so that they are easily distinguished.

The Timedivider S is used in the following way. It is placed on the chart, the parallel lines parallel to the course of the ship, the left side passing through M and the right side through N. The coloured curve through F is then noted. Next, the Timedivider S is placed on the thermogram with its left side falling along the ordinate corresponding to the time when M was passed. From the intersection between the right side and the ordinate corresponding to the time when N was passed, the parallel lines are followed towards the left till the curve noted in the series of curves is reached. This point lies on the ordinate corresponding to the time when the ship passed F, and the temperature at F may be read off.

If the operations mentioned above are carried out in reverse we can also determine by means of the Timedivider S the positions at which chosen temperatures (e. g., a temperature maximum or a whole degree) occur between M and N.

**The Timedivider Compass I.**

This instrument is used for the same purpose as the Timedivider and under the same assumptions, namely, that the ships always follow the same track and that a ship maintains a constant speed throughout the voyage. The Timedivider Compass I is more expensive than the Timedivider but is more practical in use.

The Timedivider Compass I is shown diagrammatically in Figure 3. It consists of two legs, AD and BD. Between these legs is a third leg DC, whose length may be changed so that when A and B are placed on a flat surface C also will always touch it, even if the angle between AD and BD varies. The leg DC is governed by two bars HE and GE, which are firmly pivoted at the points H and G, whereas their common pivot E is movable and may be displaced along DC. The length of HE is the same as the length of DG, and the length of GE is the same as that of DH. When these requirements are fulfilled, we always have $\frac{AC}{BC} = \frac{DG}{DH}$. The compasses are arranged so that $\frac{DG}{DH} = \frac{MF}{NF}$ and consequently $\frac{AC}{BC} = \frac{MF}{NF}$.

The compasses are used in the following manner. The ship having travelled from M to N, the points of the compasses are placed on the same abscissa on the thermogram with A on the ordinate corresponding to the time of departure from M, and B on the ordinate of the time of arrival at N. If the ship has travelled in the reverse direction, B is placed at the time of departure from N, and A at the time of arrival at

M. In both cases C will indicate the ordinate corresponding to the time when the ship was at F, and the temperature at F can be read off.

**The Timedivider Compass II.**

This instrument may be used for the same purposes as the other three Timedividers and under the same suppositions. Its construction is shown diagrammatically in Figure 4.

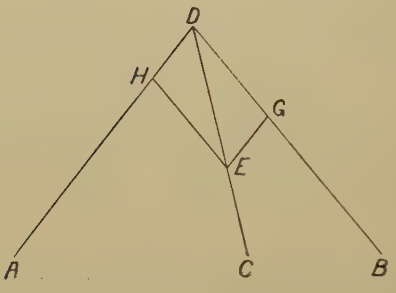


Figure 3. Timedivider Compass I.

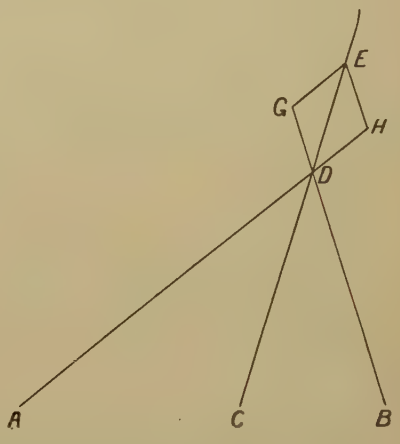


Figure 4. Timedivider Compass II.

DG = DH and EH = EG. At D, E, H, and G are pivots. E can be displaced along DC when the legs are opened or closed. This bar system is arranged so that the leg DC always will bisect the angle between DA and DB when these legs are moved. The lower part of DC can be displaced so that C always touches a flat surface when A and B are placed on the same surface. When these requirements are fulfilled we always have $\frac{AC}{BC} = \frac{AD}{BD}$. If we choose $\frac{AD}{BD} = \frac{MF}{NF}$, then $\frac{AC}{BC} = \frac{MF}{NF}$.

The compasses may be used in the same manner as the Timedivider Compass I. If, however, the compasses are made so that the length of one of the legs, e. g., AD can be varied, the same compasses may be used also for other pairs of harbours (M' and N') and other fixed points (F').

When one leg is adjustable, as above mentioned, the Timedivider Compass II can also be used for the same purpose as the Timedivider S, viz., when the positions M and N vary in relation to F from voyage to voyage. The Timedivider Compass II is then placed with B at N on the track chart, and the length of AD is adjusted so that C falls on F when A is placed on M. Then the compasses are placed on the thermogram with all the points on the same abscissa and with A on the ordinate

corresponding to the time of passing through M, and B on the ordinate corresponding to the time of passing through N. C will then indicate the time of passing through F, and the temperature at F is then found from the ordinate on which C rests.

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Sigmund Næsse has recently constructed a new diagram that in some cases is more convenient than the Timedivider S or the Timedivider Compass II (e. g., when the position of the ship is recorded at the times 2, 6, 10 a. m. and 2, 6, 10 p. m.). Its construction is shown in Figure 5.

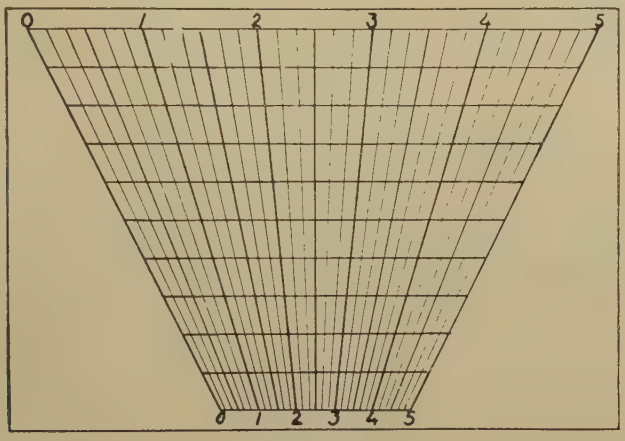


Figure 5.

The diagram is drawn on transparent celluloid. To determine the temperature at F by means of this diagram it is first necessary to reckon the time taken by the ship on passage from M to N. Then the diagram is placed on the chart so that the parallel lines on the diagram are parallel to the course of the ship, and so that the 0-line passes through M and the line corresponding to the time of the passage from M to N passes through N. The line through F then corresponds to the time taken in travelling from M to F. This time is then added to the time when M was passed, and the temperature at F can then be read off.

# Quelques Cas Tératologiques chez les Poissons.

Par

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Office Scientifique et Technique des Pêches Maritimes.

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CHEZ les poissons on trouve assez souvent des individus s'écartant du type normal par des malformations très apparentes. Les principaux cas observés furent décrits par divers auteurs et des opinions furent émises, parfois contradictoires.

Dans le courant de l'année 1943 il nous a été possible d'examiner différents cas tératologiques trouvés parmi le poisson débarqué par les chalutiers de La Rochelle. Nous les avons réunis ici, donnant à cette occasion un bref résumé des travaux qui se rapportent aux différents cas étudiés.

## Poissons Mops.

C'est à un arrêt de la croissance pendant les stades embryonnaires qu'il faut attribuer des malformations de la tête que l'on observe parfois chez certains poissons. E h r e n b a u m nomme ces malformations des mots allemands de "Mopsköpfe" et "Rundköpfe" ce que nous pouvons traduire en français par tête de roquet et tête ronde. On les rencontre assez souvent chez les gadidés (Eglefin, Morue ...) et nous avons pu observer deux cas de poissons "Mops" chez le *Trigla lyra.*

D'après cet auteur il s'agit d'un freinage de la croissance en longueur de la tête, freinage causé par une pression anormale du vitellus. Cette pression provoque un raccourcissement de la partie antérieure du crâne et, selon les cas, de la mâchoire supérieure seule (Mopsköpfe) ou des deux mâchoires (Rundköpfe).

Chez les deux Trigla mops que nous avons pu recueillir, la partie antérieure du crâne, au lieu d'être fuyante comme chez les individus normaux, était à peu près droite et tombait d'aplomb sur la mâchoire supérieure. La mâchoire inférieure atteignait l'extrémité de la mâchoire

supérieure. L'oeil était de proportion normale et, par suite du raccourcissement de la tête, au lieu d'être compris une fois et demi dans l'espace postorbitaire, son diamètre n'y était plus compris qu'une seule fois.

Le reste du corps était absolument normal; la tête seule était déformée comme le montrent les figures.

Fig. 1. *Trigla lyra mops* (original) et normal (d'après Le Danois).

## Malformation des Nageoires Pectorales chez la Raie.

Les raies montrent parfois des anomalies curieuses dont la plus fréquente semble être la présence d'une entaille dans la partie antérieure de la nageoire pectorale. Elle peut exister d'un côté seulement ou des deux côtés de la tête. Nous avons pu l'observer chez une raie douce (*Raja brachyura* Lafont.) chez qui une profonde encoche séparait la tête de la partie antérieure des ailes.

Cette raie, un jeune mâle, mesurait 41·5 cm. depuis la pointe du museau jusqu'au bout de la queue. La queue mesurait 19·5 cm., soit un peu moins de la moitié du corps, ce qui est une proportion normale. La longueur maximum des ailes était de 28·7 cm. ce qui est encore normal. Voici, à titre d'indication, les autres mesures:—

| | | |
|---|---|---|
| Distance | interorbitaire ..... | 2 cm. |
| „ | préorbitaire ..... | 6 cm. |
| „ | prénasale ..... | 4·8 cm. |
| „ | internasale ..... | 2·5 cm. |
| „ | préanale ..... | 19·5 cm. |

Les pectorales, au lieu de commencer tout près de la pointe du museau pour former le disque caractéristique, étaient séparées de la tête par deux profondes entailles triangulaires. Le fond de l'entaille droite était à 9 cm. de la pointe du nez et le fond de la gauche à 8 cm. La partie antérieure de chaque aile s'avançait en une pointe légèrement recourbée vers l'axe du corps, la droite à 3·7 cm. du bout du museau et la gauche à 2·6 cm.

La malformation du disque n'était donc pas symétrique des deux côtés. Pour la pectorale droite elle était plus accusée, l'encoche atteignant la première fente branchiale alors que pour la gauche il s'en fallait d'un centimètre.

La face supérieure du disque était entièrement sans épine sauf dans sa partie antérieure avec en avant de l'orbite deux épines et deux autres en arrière. Sur le dos et sur la queue une série de 28 épines médianes débutait un peu en arrière des évents et deux épines isolées se trouvaient chacune de chaque côté de la partie antérieure de la ligne médiane. Les bords de la queue portaient une série de fines épines.

La face ventrale était entièrement lisse, exception faite d'une légère frange très faiblement épineuse sur la marge antérieure des ailes et du museau.

La coloration était normale et caractéristique de l'espèce mais une bande blanchâtre, non pigmentée, longue de 6 cm., débutait au fond de l'entaille et se dirigeait vers le milieu de l'aile tout en restant parallèle au bord du disque. De même au bord de l'entaille gauche, et toujours sur

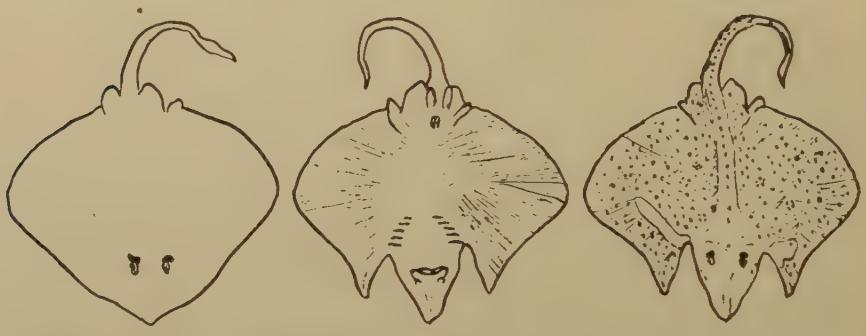

Fig. 2. *Raja brachyura* anormale (faces dorsale et ventrale) comparée avec un individu normal.

l'aile, se trouvait une tache également blanchâtre, mais plus large et moins étendue (2·5 cm.).

Lewis Radcliffe a décrit dans "Natural History" un cas semblable chez une raie américaine, *Raja stabuliforis*, ou l'entaille droite était également plus profonde que la gauche et atteignait la troisième fente branchiale alors que la gauche s'arrêtait à la seconde.

Il explique ce phénomène par le fait que, chez l'embryon de la raie, les pectorales sont d'abord du type requin, sans liaison avec la tête. Au cours du développement les nageoires croissent antérieurement plus vite que ne se fait latéralement la fusion avec la tête, mais cette fusion s'opère tout de même et finalement les pectorales deviennent confluentes avec la tête comme cela s'observe chez les raies normales. Cependant dans quelques cas particuliers cette fusion ne s'opère pas et nous avons des individus anormaux qui furent d'abord décrits comme des espèces nouvelles, tels le *Propterygia hypostica* de A. W. Otto (1821) et le *Hieroptera abredonensis* de John Flemming (1841).

Depuis on a reconnu qu'il s'agissait uniquement de cas anormaux

(Müller-Henle, Lütken, Gill ..) que l'on a observé et reconnus chez *Raja punctata* (Beltremieux), *R. clavata, R. macrorhynchus* (L. Alejos Sanz) et, comme pour notre exemple, chez *R. brachyura* (Bureau).

## Quelques cas d'Ambicoloration chez la Plie.

Nous avons eu l'occasion de recueillir plusieurs plies (*Pleuronectes platessa*) présentant des colorations anormales sur le côté aveugle qui, à l'ordinaire, est naturellement plat et blanchâtre. Lorsque le pigment se développe ainsi sur la face aveugle comme sur le côté oculaire du poisson, on a, selon le terme proposé par Cunningham, un cas d'ambicoloration. De tels cas sont plus ou moins rares selon les espèces de

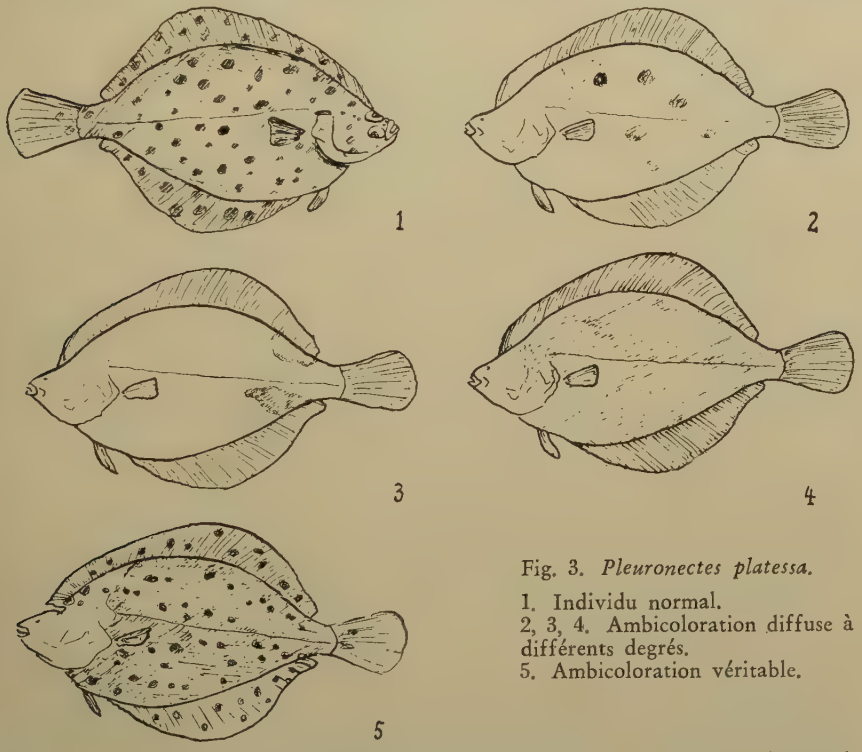


Fig. 3. *Pleuronectes platessa.*

1. Individu normal.
2, 3, 4. Ambicoloration diffuse à différents degrés.
5. Ambicoloration véritable.

pleuronectes: chez la plie ils sont assez fréquents, chez la sole ou la limande sole ils sont très rares.

Chez les pleuronectes les yeux sont situés tous deux sur la même face mais leur larve possède un oeil en position normale sur chaque côté de la tête. Au cours du développement un de ces yeux, le gauche chez la plie, migre sur l'autre face peu à peu repoussé par un repli en creux de la peau qui enserre l'oeil et le pousse lentement sur la face droite qui devient alors le côté oculaire. La face aveugle, en contact avec le fond lorsque la plie ne nage pas, reste blanchâtre, tandis que sur

le côté oculaire des pigments se développent qui donneront à la plie sa coloration caractéristique — les mélanophores brun-noir et les xanthophores orangés. A ces deux pigments s'ajoutent encore les guanophores, cellules qui réfléchissent plus ou moins la lumière incidente.

Dans les cas d'ambicoloration le pigment se développe sur le côté aveugle comme sur le côté oculaire mais avec une intensité variable. J. R. Norman, à qui nous empruntons les traits principaux de cette étude, distingue trois catégories qu'il nomme "training, spotting, and true ambicoloration".

Ambicoloration diffuse: le développement des chromatophores dans certaines régions de la peau du côté aveugle produit des taches, d'une pigmentation terne, qui lui donnent un aspect maculé. Le côté aveugle est bien moins coloré que l'autre, sans taches ni marques caractéristiques comme sur le côté oculaire.

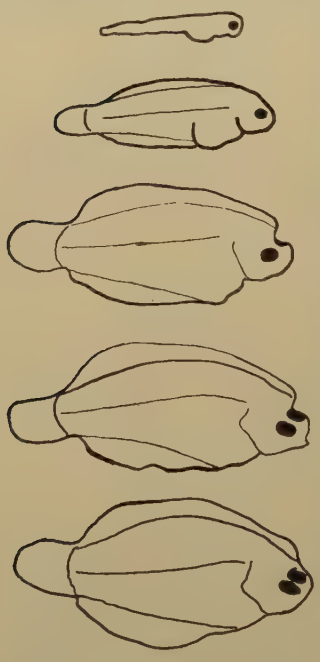

Fig. 4. Divers stades du développement de la Plie d'après Norman.

Ambicoloration en taches: il existe un nombre variable de taches noires ou brunes, souvent irrégulières et donnant un aspect bigarré comme celui déjà décrit pour la face oculaire. Les taches ont parfois une disposition régulière; quelques turbots présentent parfois une série de grandes taches noires et rondes tout le long du contour du corps sur la face aveugle avec ou non une tache supplémentaire sur la ligne latérale.

Ambicoloration véritable: les deux faces ont une coloration à peu près identique et une disposition semblable des taches. Le plus souvent l'ambicoloration n'est pas complète et la partie antérieure du corps reste blanche. Dans presque tous les cas il reste au moins une tache blanche au bout de la tête.

Parmi les plies que nous avons pu examiner, trois correspondaient au premier cas distingué par Norman en ce sens que leur face aveugle était, à divers degrés, colorée en brun clair, bien moins foncé que sur la face oculaire et sans aucune pigmentation orangée. Chez la première la face aveugle portait plusieurs petites taches arrondies et brun clair. Chez la seconde l'anomalie consistait en deux taches irrégulières d'un brun très clair, partant de la région caudale pour s'étendre de chaque côté de la ligne latérale. Enfin chez la troisième la face aveugle était uniformément pigmentée en brun clair, la région de la tête étant un peu plus pâle et le pigment y apparaissant en points plus isolés. Par tous leurs autres caractères ces plies étaient parfaitement normales.

La dernière examinée se rapporte au cas de l'ambicoloration véritable. Chez une plie longue de 30 cm. le côté gauche était entièrement coloré, à l'exception de la tête qui était blanche et séparée de la partie pigmentée par le bord de l'opercule. Les taches orangées ne se correspondaient pas parfaitement d'une face à l'autre mais l'allure et l'intensité de la coloration étaient identiques sur les deux faces.

Quand l'ambicoloration est ainsi à peu près totale elle est, remarque Norman, presque toujours accompagnée de modifications dans la symétrie du poisson, d'un retard dans la migration de l'oeil, de modifications de la forme des écailles et de la taille des nageoires paires.

Fig. 5. A, vue de la tête, montrant la houppe charactéristique.
B, vue de face montrant la face aveugle nettement bombée.

Notre plie montrait une face aveugle colorée mais aussi nettement plus bombée que le côté droit ce qui est remarquable. La bouche était normale. Au dessus de l'oeil un sillon assez profond le séparait du premier rayon de la dorsale qui prenait naissance sur une sorte de houppe charnue s'avançant au dessus de lui.

Chez les pleuronectes la migration de l'oeil est terminée avant que ne se produise l'extension en avant de la nageoire dorsale. Chez les individus ambicolorés cette migration semble arrêtée ou retardée. Il en résulte un obstacle pour la croissance en avant de la dorsale qui vient former une houppe charnue au dessus de l'oeil. Cette houppe ne s'observe que lorsque l'ambicoloration est totale ou presque, selon Cunningham chez tous les individus ou le pigment est développé au moins au delà d'une ligne passant par l'opercule. C'est ce que l'on observait chez notre plie ou cette houppe était très nettement visible.

Les écailles cycloïdes étaient identiques sur les deux faces.

Enfin chez les pleuronectes normaux la nageoire pectorale du côté oculaire est plus grande que celle du côté aveugle alors que chez les individus ambicolorés la nageoire du côté aveugle est souvent un peu plus

grande que de coutume. Ici les nageoires droite et gauche mesuraient respectivement 33 et 25 mm.

Quant à l'explication même de ce phénomène elle reste encore véritablement à trouver car, si l'on a proposé diverses théories, aucune n'a encore été acceptée comme pleinement satisfaisante. Retenons en deux. Pour les uns, l'ambicoloration serait due à l'action de la lumière s'exerçant plus longtemps sur la face aveugle des poissons chez qui la migration de l'oeil est retardée et qui, par suite, nagent plus longtemps en position verticale normale. Pour les autres ce phénomène ne serait qu'une tendance au retour vers la symétrie bilatérale des ancêtres des pleuronectes.

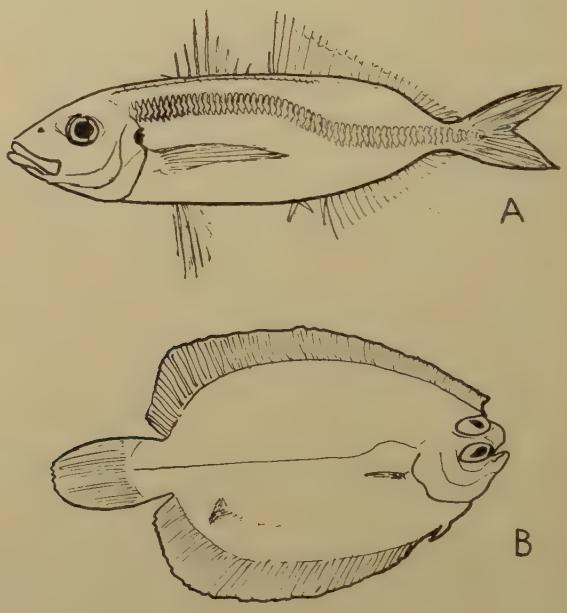


Fig. 6.
Poissons à queue courte.
A. *Trachurus trachurus* subsp. *mediterraneus*
B. *Pleuronectes microcephalus*.

## Poissons à Queue courte.

On rencontre assez souvent des poissons présentant un raccourcissement caudal très apparent. P. Desbrosses a étudié cette anomalie chez la dorade (*Pagellus centrodontus*). Ce raccourcissement peut venir de la soudure ou du raccourcissement d'un certain nombre de vertèbres ou encore d'une torsion du squelette. Dans les cas de vertèbres soudées cette soudure porte principalement sur les vertèbres caudales. Desbrosses rapproche le cas de la dorade de cas semblables observés chez les salmonidés, le brochet, l'anguille, les mugilidés, la limande-sole, la morue, le haddock ... Quant à nous, nous avons pu l'observer chez la sardine, le chinchard, et la limande-sole, poissons chez qui le raccourcissement provenait de la soudure d'un certain nombre de vertèbres caudales.

Chez le chinchard nous avons trouvé deux cas présentant cette anomalie. Le nombre des vertèbres était normal (10/14) mais sept caudales étaient soudées et aplaties. Ce chiffre est légèrement supérieur à celui que l'on note d'ordinaire et qui varie de deux à six. La longueur de la partie caudale de la colonne vertébrale est toujours supérieure à celle de la partie abdominale et le rapport entre les deux est de 1·7 chez le chinchard normal. Dans les deux cas de soudure de vertèbres il n'est plus que de 1. La partie caudale de la colonne vertébrale très diminuée est devenue égale à la partie abdominale ce qui donne à la partie postérieure du poisson une allure comprimée très particulière. Les boucliers de la ligne latérale restent en nombre normal mais ils se ressèrent les uns les autres et les derniers rayons des nageoires dorsales et ventrales viennent recouvrir la naissance de la caudale.

L'explication de cette anomalie reste en suspens bien que l'on soit en présence de diverses hypothèses: mutations, maladie osseuse, action de facteurs physiques externes, contraction de certains muscles ... Dans son étude, Desbrosses n'en retient aucune comme plus particulièrement valable.

Le rapprochement entre ces différents cas et les explications proposées montre que, mis à part le cas des poissons à queue courte qui se rattacherait plutôt aux phénomènes de maladies osseuses, dans tous les autres cas un mauvais développement embryonnaire semble suffisant pour expliquer les anomalies constatées.

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# Note sur les Caractères Sexuels Secondaires du *Callionymus lyra.*

Par

**R. Letaconnoux.**

CHEZ le Callionyme ou Poisson Lyre, il existe entre le mâle et la femelle, des différences très nettes qui permettent de les distinguer facilement. Le mâle en particulier possède une papille anale et une première dorsale beaucoup plus haute que la seconde, ces deux nageoires se raccordant presque par leur base. Chez la femelle au contraire la papille anale est indistincte et les deux nageoires dorsales sont nettement séparées, la première étant plus petite que la seconde.

Nous avons recherché les différences qui peuvent exister entre mâles et femelles dans les proportions relatives du corps ainsi que dans la variation du nombre de rayons des nageoires.

**Tableau 1.**

| Sexe | Nombre d'individus | Long. Tête / Long. Totale | Largeur Tête / Long. Totale | 1er ε · D1 / L. T. | 1er ε · D2 / L. T. | Pectorale / L. T. | Ventrale / L. T. |
|---|---|---|---|---|---|---|---|
| ♂ | 20 | 0·215 | 0·193 | 0·334 | 0·126 | 0·148 | 0·155 |
| ♀ | 20 | 0·203 | 0·199 | 0·085 | 0·121 | 0·147 | 0·155 |

| | | N. de Rayons | | | | | |
|---|---|---|---|---|---|---|---|
| | | D1 | D2 | Anale | Caudale | Ventrale | Pectorale |
| ♂ | 20 | 4 | 9 | 9 | 12 | 1—5 | 20(19 à 21) |
| ♀ | 20 | 4 | 9 | 9 | 12 | 1—5 | 20(19 à 21) |

Taille moyenne: ♂ 211, ♀ 183 mm.

Il apparaît tout de suite que les caractères numériques sont fixes et semblables chez les mâles et les femelles. Seule la pectorale montre une légère variation dans le nombre de ses rayons mais la moyenne est identique chez les deux sexes.

Les nageoires pectorales et ventrales ont une taille relative tout à fait identique chez les mâles et les femelles. Les différences portent surtout sur la taille du premier rayon de la première dorsale qui est beaucoup

plus importante chez le mâle alors que le premier rayon de la seconde dorsale a une taille relative à peu près semblable chez les deux sexes sinon un peu plus forte au bénéfice des mâles.

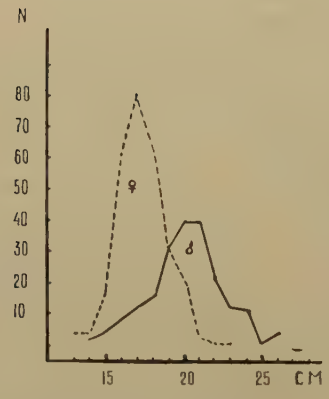
La tête enfin montre aussi une légère différence, celle des mâles étant relativement plus longue et plus étroite que celle des femelles.

Nous mettrons encore en valeur deux caractères déjà notés par d'autres auteurs et se rattachant aussi aux différences entre les deux sexes. Dans un même lot de *Calliorymus lyra* :—

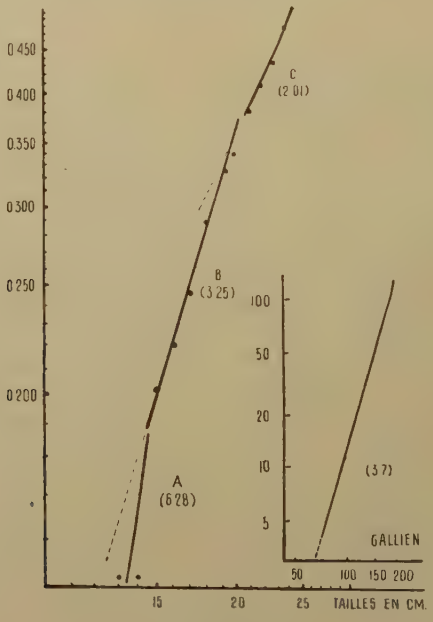
la taille moyenne des mâles est supérieure à celle des femelles,

le nombre des mâles est plus petit que celui des femelles.

Le graphique No. 1 illustre ces différences. Sur un lot de 491 individus la taille moyenne des femelles se situe autour de 17 cm. tandis que celle des mâles se place entre 20 et 21 cm. Sur un total de 784 individus nous avons séparé 322 mâles et 462 femelles soit 41 et 59 %.




Graphique 1. Taille des mâles et des femelles.




Graphique 2.

Gallien a publié une étude sur la croissance relative des deux nageoires dorsales chez le mâle (Bull. Soc. Zool. Fr. t. LIX, no. 2, p. 135.). D'après le résultat de mensurations effectuées sur 55 individus compris entre 4 et 18 cm. il a pu montrer que le premier rayon de la première dorsale du mâle qui est un caractère sexuel secondaire particulièrement net, a une croissance disharmonique telle que le taux de dysharmonie atteint 3·70. Par contre le premier rayon de la seconde dorsale qui n'est pas un caractère sexuel secondaire a une croissance harmonique.

Ayant pu nous procurer un matériel assez abondant nous avons repris cette étude, calculant pour 179 mâles le rapport:— Longueur du premier rayon de la première dorsale/Longueur totale du corps. Puis nous avons calculé l'indice moyen pour chaque taille entre 13 et 24 cm. (Tableau No. 2).

**Tableau 2.**

| Taille | Indice | n | Taille | Indice | n | Taille | Indice | n |
|---|---|---|---|---|---|---|---|---|
| 13 | 0·153 | 2 | 17 | 0.248 | 8 | 21 | 0·378 | 32 |
| 14 | 0·153 | 7 | 18 | 0·287 | 16 | 22 | 0·411 | 16 |
| 15 | 0·203 | 8 | 19 | 0·325 | 27 | 23 | 0·429 | 6 |
| 16 | 0·222 | 21 | 20 | 0·340 | 27 | 24 | 0·471 | 9 |

Ces résultats sont portés sur le graphique No. 2 où en ordonnée figurent les indices et en abscisse les tailles (en coordonnées logarithmiques). Nous obtenons ainsi trois segments de droite A, B, et C pour lesquels le taux de dysharmonie est donné par les valeurs:

$$\mathrm{Tg}\,\alpha : 6{\cdot}28 \qquad \mathrm{Tg}\,\beta : 3{\cdot}25 \qquad \mathrm{Tg}\,\gamma : 2{\cdot}01$$

La valeur que nous trouvons ici pour $\beta$ est très voisine de celle obtenue par G a l l i e n mais au lieu d'une droite unique nous trouvons trois segments de droite de pente de plus en plus faible indiquant une diminution avec l'âge de la vitesse de croissance relative du premier rayon de la dorsale.

G a l l i e n fait observer dans son travail qu'il y a une remarquable différence dans l'allure de la croissance des deux dorsales qui sont des organes morphologiquement identiques mais dont l'un est lié à la sexualité mâle et qui, par suite, peut être considéré comme un caractère sexuel secondaire.

Nous ajouterons qu'il a bien la valeur d'un caractère sexuel comme organe permettant à première vue de distinguer le mâle de la femelle (G a l l i e n : La sexualité) mais que sa croissance n'est pas par contre celle d'un véritable caractère sexuel secondaire. On admet en effet que la croissance d'un tel caractère est sous la dépendance des hormones sexuelles qui provoquent dans un organe déterminé, et à partir de la puberté, une modification du taux de croissance par rapport à l'ensemble du corps. (A b e l o o s : La croissance).

Dans le cas actuel l'analyse détaillée du phénomène montre que la croissance passe par deux stades critiques entre 14 et 15 cm. puis entre 20 et 21 cm. et qu'après chacun de ces stades le taux de dysharmonie diminue. Il en résulte que le taux est plus élevé chez le jeune que chez l'adulte et qu'en somme le développement du caractère sexuel se fait à un taux supérieur chez l'individu non soumis à l'influence des glandes génitales.

Nous considérerons donc plutôt la présence du premier rayon de la dorsale chez le *Callionymus lyra* mâle comme un caractère sexuel neutre,

indicateur du sexe, mais non en relation directe avec la sexualité mâle puisque le développement des glandes génitales chez l'adulte agit sur lui non par un relèvement mais au contraire par une diminution du taux de croissance qui passe de 6·28 à 3·25 au moment de la maturité puis à 2·01 lorsque la mortalité commence à s'exercer sur les mâles (voir courbe de population).

En résumé chez le *Callionymus lyra* les mâles et les femelles se distinguent par une série de caractères particulièrement nets:— Taille moyenne des individus, proportion des sexes, croissance relative de la tête et du premier rayon de la dorsale. En ce qui concerne ce dernier caractère l'étude montre que chez le mâle le taux de dysharmonie élevé qui en caractérise la croissance subit avec l'âge une forte réduction.

# Dimorphisme Sexuel chez quelques Téléostéens de la Côte Atlantique Française.

Par

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IL peut être utile de connaître le sexe d'un poisson sans être obligé d'ouvrir l'abdomen de ce poisson. Cette distinction extérieure du sexe est facile chez les squales et les raies où le mâle est pourvu d'organes d'accouplement, mais difficile chez la plupart des téléostéens.

Les différences sexuelles externes de cinq espèces communes en Atlantique et d'aspects bien différents ont été examinées:—

—Le Merlan, *Gadus merlangus* L.

—Le Saint-Pierre, *Zeus faber* L.

—Le Rouget-barbet, *Mullus barbatus* (Rond.) *surmuletus* (Fage)

—La Cépole rougeâtre, *Cepola rubescens* L.

—Le Callionyme lyre, *Callionymus lyra* L.

Rappelons d'abord que pendant la période de reproduction, les femelles adultes du merlan et du rouget se reconnaissent à première vue à leur abdomen gonflé d'ovules mûrs. Ainsi les femelles qui n'ont pas terminé leur ponte sont faciles à déterminer, chez le merlan de février à mai, chez le rouget-barbet en mai et juin. Néanmoins, vers la fin de la période du frai, on peut prendre pour un mâle une femelle vidée de ses ovules. Il est fréquent aussi que l'on se trompe sur le sexe d'un merlan mâle à l'estomac bien rempli.

D'autre part, le mâle de *Callionymus lyra* L. se reconnaît aisément à sa livrée et à sa papille génitale, laquelle manque chez la femelle.

Les sexes des cinq espèces étudiées peuvent se reconnaître à la taille et aux caractères numériques ou métriques.

## Tailles.

Chez la plupart des téléostéens, la femelle grandit plus rapidement que le mâle, aussi à longévité égale, les mâles atteignent-ils des tailles bien inférieures à celles des femelles. Chez ces espèces, à partir d'une

certaine taille, la proportion des mâles diminue rapidement, puis à des longueurs plus grandes il n'y a plus que des femelles.

C'est ce qu'on observe chez trois de nos poissons.

**Merlan** — Le plus grand merlan que nous ayons rencontré mesurait 68 cm., c'est une femelle. Cette taille considérable a été déjà signalée en Islande (S c h m i d t 1905), mais jamais encore dans nos eaux. Le plus grand mâle observé par nous mesure 53 cm. seulement (il s'agit de la longueur totale maxima mesurée du museau à l'extrémité du rayon le plus long de la nageoire caudale).

De 54 à 68 cm. tous les merlans sont des femelles. De 40 à 53 cm., les femelles prédominent. De 24 à 39 cm., les deux sexes sont également représentés. Dans les petites tailles, jusqu'à 23 cm., les mâles sont plus nombreux.

**Saint-Pierre** — Le Saint-Pierre, mesuré de l'extrémité de la mâchoire inférieure, bouche fermée, à l'extrémité du rayon le plus long de la nageoire caudale, atteint la taille maxima de 66 cm. Le plus grand mâle rencontré mesurait 46 cm.

De 7 à 27 cm., il y a 54 % de mâles; de 28 à 46 cm., 54 % de femelles; de 47 à 66 cm., 100 % de femelles.

**Rouget-barbet** — Le barbet peut atteindre la longueur de 42 cm., mais les mâles ne dépassent pas 38 cm. Les mensurations sont faites de l'extrémité du museau au milieu de la ligne joignant les deux pointes de la nageoire caudale.

De 10 à 21 cm., les mâles sont plus nombreux — 65 à 89 % suivant les lots. De 22 à 32 cm., les femelles prédominent — 62 à 77 %. De 33 à 38 cm., les mâles sont extrêmement rares, — moins de 9 %. Enfin de 39 à 42 cm., il n'y a que des femelles. Il y a donc plus de 90 chances sur 100 pour qu'un rouget mesurant plus de 32 cm. soit une femelle.

Il a été montré par l'étude de l'âge et des classes annuelles, que les mâles naissent en plus grand nombre et que leur taux de mortalité après l'acte de reproduction est plus élevé que celui des femelles. (D e s - b r o s s e s 1935).

**Cépole Rougeâtre** — Chez le poisson ruban, au contraire de ce que nous venons de voir, c'est le mâle qui atteint la plus grande taille. La croissance est probablement ralentie chez les femelles, celles-ci parvenant à maturité à la taille de 30 cm. et les mâles seulement à partir de 37 cm.

Les dimensions de cette espèce sont mesurées jusqu'à l'extrémité de la plaque verticale de Cuvier, la nageoire caudale, fragile, étant souvent incomplète. (A. M. W i r k e r 1932, a fait de même en Méditerranée.)

La taille maxima, ainsi mesurée, est de 69·6 cm.; la plus grande femelle ne mesure que 52 cm.

Jusqu'à 45 cm. de longueur, les deux sexes sont également représentés; de 46 à 52 cm. les femelles sont rares — 16 %; à 53 cm. et au-dessus, il n'y a que des mâles.

**Callionyme lyre** — Tous les individus de grande taille mesurant 25 cm. et plus de longueur totale, sont des mâles; la croissance semble plus lente

chez les femelles: à la taille de 24 cm. les mâles portent 3 anneaux d'hiver sur les otolithes et une femelle a 5 anneaux.

Ces diverses répartitions des sexes par groupes de tailles tirent leur valeur du nombre important d'exemplaires examinés, nombre variant suivant l'espèce de 600 à 3,000.

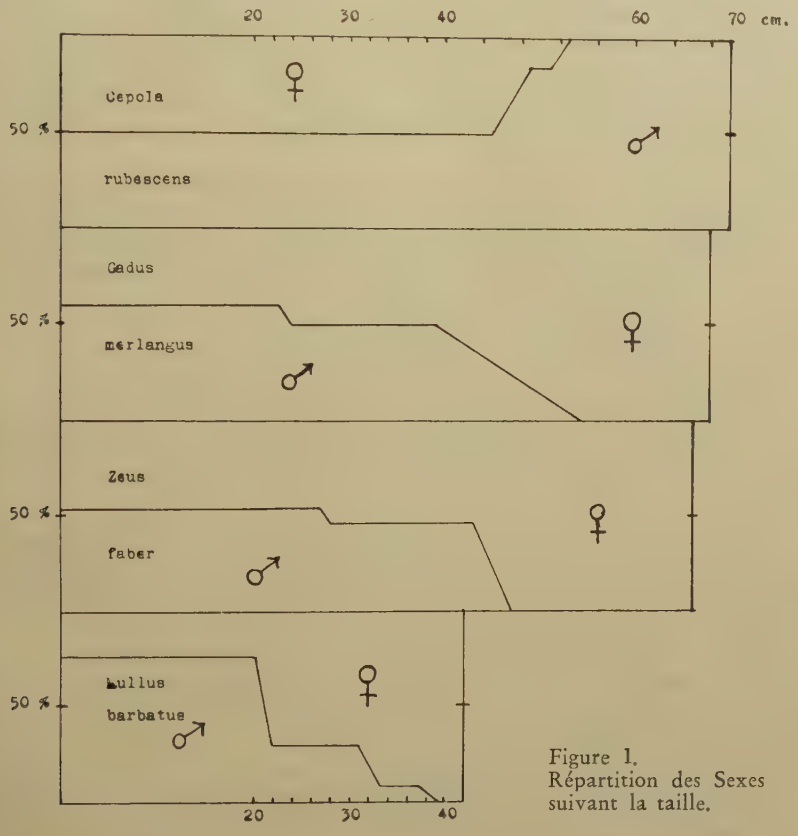


Figure 1.
Répartition des Sexes suivant la taille.

## Caractères numériques.

**Saint-Pierre** — Chez le Saint-Pierre de notre côte, le nombre des rayons aux deux nageoires dorsales varie de 32 à 35. Le nombre le plus fréquent est chez les mâles de 34, chez les femelles de 35.

Les Saint-Pierre se répartissent ainsi d'après le nombre des rayons qui soutiennent les nageoires du dos:—

| | | |
|---|---|---|
| St-Pierre ayant aux nageoires dorsales: | 32 ou 33 rayons | : 90 % sont des mâles. |
| | 34 rayons | : 65 % sont des mâles. |
| | 35 rayons | : 80 % sont des femelles. |

La seconde nageoire anale est pourvue de 21 à 24 rayons. Le nombre le plus fréquent est 22 chez les mâles, 23 chez les femelles.

A ce point de vue la répartition des sexes est la suivante:—

| | | |
|---|---|---|
| St-Pierre ayant à la seconde nageoire anale: | 21 ou 22 rayons | : 76 % sont des mâles. |
| | 23 rayons | : 62 % sont des femelles. |
| | 24 rayons | : 87 % sont des femelles. |

Ainsi, sauf de rares exceptions, un St-Pierre qui possède 32 ou 33 rayons aux nageoires dorsales et 21 ou 22 rayons à la 2ème anale est un mâle. Un Zeus qui porte 35 rayons de nageoires sur le dos et 24 rayons mous derrière l'anus est une femelle. Par contre on hésitera sur la détermination du sexe d'un poisson ayant 34 rayons à $D^1$ et $D^2$ et 23 rayons à $A^2$.

Ce caractère sexuel secondaire, établi sur 480 exemplaires, est valable: les triangles de fluctuations probables des moyennes des deux sexes sont nettement distincts et le rapport de la différence des moyennes à leur erreur probable est bien supérieur à 3 pour l'une et l'autre nageoires.

A la disparition chez les mâles d'un rayon aux nageoires impaires, correspond une moyenne vertébrale relativement réduite. Le nombre des vertèbres (urostyle inclus) varie de 31 à 33 dans les 2 sexes et est le plus souvent de 32. Tandis que la moyenne des femelles est 32·07, celle des mâles est 31·79. Les triangles de fluctuation probable de ces moyennes sont bien séparés et le rapport de la différence des moyennes à leur erreur probable est de 8·8. Ce caractère sexuel est donc valable.

Parmi les St-Pierre à 31 vertèbres: 88 % sont des mâles.
Parmi les St-Pierre à 33 vertèbres: 93 % sont des femelles.

La race localisée près des côtes de Mauritanie, du Sénégal, et de Guinée, que nous avons dénommée *Zeus faber mauritanicus,* ne présente pas de différence sexuelle dans le nombre des rayons aux nageoires impaires, ni dans celui des vertèbres (Desbrosses 1937).

La distinction des deux sexes par des caractères numériques est rare chez les poissons. Ce dimorphisme vertébral a été signalé à notre connaissance chez le sagre, *Spinax niger* Cloquet (♂ : 44·62; ♀ : 45·06) (Punnett 1904); chez l'anchois du Pacifique, *Engraulis mordax mordax* (♂ : 45·77, ♀ : 45·65) (Hubbs 1925); chez le capelan, *Mallotus villosus* (Muller) (♂ : 65·65, ♀ : 65·13) (Hart 1937).

## Caractères métriques ou plastiques.

**Merlan** — Le rayon antérieur de la première nageoire anale est situé plus en arrière chez la femelle que chez le mâle du merlan; autrement dit, la distance préanale $A_{I_1}$ est plus grande chez la femelle[1]). Cette différence s'observe sur les moyennes à toutes les tailles; mais elle est beaucoup plus nette sur les gros merlans. Considérons en effet seulement les merlans mesurant 39·5 cm. à 53 cm. (les mâles étudiés ne dépassent pas cette dernière taille de 53 cm.). Le rapport de la distance préanale

[1]) $A_{I_1}$ est mesuré parallèlement à la ligne joignant l'extrémité antérieure du museau au milieu du pédoncule caudal

(X 100) à la longueur totale (x), $\frac{100\ AI_1}{x}$, varie de 30·8 à 35·9. Il est en moyenne de 32·2 chez les mâles, de 33·7 chez les femelles.

A la taille de 40 cm., le premier rayon de l'anale est situé en moyenne à 128 mm. du museau chez le ♂ et à 134 mm. chez la ♀ ; à une longueur totale de 50 cm., la différence des deux positions est de 7 mm.

Les triangles de fluctuation probable des moyennes sont nettement séparés (♂ : 31·7 à 32·7; ♀ : 33·1 à 34·2); et l'erreur moyenne de la différence des valeurs moyennes est de 6·9. Ce caractère est donc valable.

Il est plus variable chez la femelle; le coefficient de variabilité ($C = \frac{100\ \sigma}{M}$) = 3·11 pour la ♀ ; = 2·29 pour le ♂.

Les deux sexes se répartissent ainsi d'après 70 exemplaires:—

| $\frac{100\ AI_1}{x}$ = | 30·8 à 31·8 | 31·9 à 32·6 | 32·7 à 33·9 | 34 à 35·9 |
|---|---|---|---|---|
| ♂ | 90 | 67 | 27 | 0 |
| ♀ | 10 | 33 | 73 | 100 |

La plupart des merlans présentant un rapport $\frac{AI_1}{x}$ inférieur à 0·326 sont des mâles; ceux dont la même proportion est supérieure à 0·326 sont des femelles généralement.

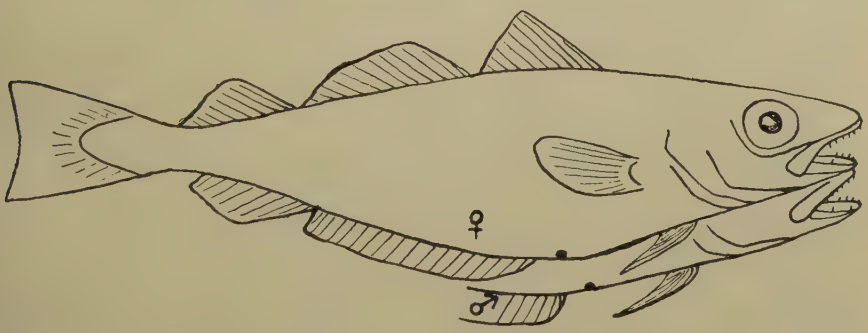


Figure 2. *Gadus merlangus* ♀ et ♂. Chez le mâle, l'extrémité des nageoires ventrales arrive à l'anus, dont la position est plus avancée que chez la femelle.

Il découle de cette différence sexuelle dans la position de la première anale que chez les gros merlans, les nageoires ventrales arrivent jusqu' auprès de l'anus chez les mâles; tandis que leur extrémité est bien en avant de l'anus sur les femelles.

**Saint-Pierre** — Parmi les St-Pierre mesurant 20 à 46 cm., la distance interorbitaire (IO) des mâles est en moyenne plus large que celle des femelles; en outre la distance mesurée du museau à l'insertion du premier rayon de la seconde anale ($AI_2$) est, en moyenne et à taille égale, plus petite chez le mâle ou égale dans les deux sexes. Il s'ensuit que le rapport $\frac{100\ IO}{AI_2}$ est en moyenne plus grand chez le mâle.

Nous mesurons IO au compas, entre les deux crêtes osseuses limitant dorsalement la cavité orbitaire. $A_{I_2}$ est la distance antérieure à la seconde anale, son premier rayon étant redressé. Le poisson étant placé bouche fermée sur une règle graduée avec butoir, $A_{I_2}$ est mesurée parallèlement à la droite joignant le point de butée de la mâchoire inférieure au milieu du pédoncule caudal. (cf. Desbrosses 1937, Fig. 2).

Considérons seulement les St-Pierre de 23 à 46 cm. La proportion $\frac{100\ IO}{A_{I_2}}$ est chez les mâles en moyenne de 8·80; et la fluctuation probable de cette moyenne va de 8·59 à 9·01. Les femelles ont une moyenne de 8·24 et la fluctuation probable de cette moyenne va de 7·96 à 8·52. Le rapport de la différence des moyennes à leur erreur probable est de 5·2. Ce caractère sexuel secondaire est valable.

D'après 88 échantillons mesurant au moins 23 cm. voici le pourcentage des mâles et des femelles :—

| $\frac{100\ IO}{A_{I_2}}$ = | 6·6 à 8 | 8·1 à 8·5 | 8·6 à 9·3 | 9·4 à 10 |
|---|---|---|---|---|
| ♂ | 0 | 47 | 67 | 100 |
| ♀ | 100 | 53 | 32 | 0 |

La variabilité de ce rapport est plus élevée chez les femelles (C : 6·8) que chez les mâles (C : 5·0).

**Rouget-barbet** — Nous avons montré, dans un travail antérieur, qu'à une taille supérieure à 17 cm. la femelle du rouget se distingue par son museau plus allongé relativement à la taille et surtout à l'oeil et par la position plus reculée de ses nageoires impaires. Les distances prédorsales et préanale sont plus grandes chez les femelles; ce caractère est valable; mais les différences entre les deux sexes qui sont en moyenne de 1·5 mm. à 3 mm. sont trop faibles pour que nous y revenions ici (Desbrosses 1936).

Le mâle, avec son museau court et ses yeux volumineux, rappelle souvent le rouget de vase de Méditerranée. Ce rapprochement est curieux car certains auteurs comme Gronovius (1780) ont pris *M. surmuletus*, le rouget de roche, pour la femelle de *M. barbatus*, le rouget de vase. La plupart des mâles ont le museau plus court ou égal à l'oeil et la majorité des femelles le museau plus long que le diamètre de l'oeil.

Chez tous les gros rougets de 18 à 34·5 cm., calculons le rapport de la distance préorbitaire (PO) au diamètre de l'oeil (O); $\frac{PO}{O}$ est en moyenne de 0·97 pour les mâles et de 1·10 pour les femelles. Lorsque l'oeil mesure 11 mm., le museau mesure 1·5 mm. de plus chez la femelle; pour un oeil de 16 mm., le museau de la femelle est plus allongé de 2 mm. en moyenne (les mensurations étaient faites au demi-millimètre près).

Les triangles de fluctuation probable de ces moyennes sont distincts (♂ : 0·94 à 1·00; ♀ : 1·06 à 1·14). L'erreur moyenne de la différence des moyennes est de 7·4.

Les sexes des barbets de 18 à 34 cm. sont ainsi répartis d'après ce rapport (tableau basé sur 182 exemplaires):—

| $\frac{PO}{O}$ = | 0·7 à 0·8 | 0·9 | 1·0 | 1·1 à 1·2 | 1·3 à 2·0 |
|---|---|---|---|---|---|
| ♂ | 100 | 76 | 51 | 20 | 0 |
| ♀ | 0 | 24 | 49 | 80 | 100 |

Ainsi que nous l'avons observé chez merlans et St-Pierre, le caractère sexuel secondaire est plus variable pour les femelles (C : 12·8) que pour les mâles (C : 10·4).

Figure 3. *Mullus barbatus*, en haut ♀, en bas ♂. Chez le mâle, l'oeil est plus gros par rapport au museau.

**Cépole Rougeâtre** — Chez le ruban, l'oeil (O) et la distance préanale (AI) sont généralement plus grands sur les femelles; par contre, les rayons de la nageoire caudale (C) sont plus allongés chez les mâles à taille égale.

Le rapport de la caudale à l'oeil, $\frac{C}{O}$, est en moyenne plus élevé chez les mâles à toutes les tailles. Si l'on ne prend que les individus de grande dimension, mesurant 37 à 52 cm. de longueur (rappelons que la longueur est mesurée jusqu'à la plaque verticale de Cuvier), $\frac{C}{O}$ est en moyenne de

5·3 pour les mâles, de 3·8 pour les femelles. Lorsque l'oeil mesure 10 mm., la nageoire caudale mesure donc en moyenne 38 mm. chez la femelle et 53 mm. chez le mâle : différence importante.

Les triangles de fluctuation probable des moyennes sont nettement séparés: 4·9 à 5·6 pour les mâles; 3·5 à 4·1 pour les femelles et le rapport de la différence des moyennes à leur erreur moyenne est 11.

Dans ces mêmes tailles, d'après 99 cépoles, les deux sexes se répartissent ainsi:—

| $\frac{C}{O}$ = | moins de 3·6 | 3·6 à 4·4 | 4·5 à 4·8 | plus de 4·8 |
|---|---|---|---|---|
| ♂ | 0 | 32 | 80 | 100 |
| ♀ | 100 | 68 | 20 | 0 |

La plupart des cépoles présentant un rapport inférieur à 4·5 sont des femelles; celles qui ont un rapport supérieur à 4·5 sont la plupart des mâles.

Cette proportion est plus variable chez les mâles (C : 15·3) que chez les femelles (C : 13·2).

Lorsque la nageoire caudale est en mauvais état, la relation précédente ne peut pas être obtenue. On peut alors déterminer le sexe en mesurant la distance préanale et en la rapportant à la longueur. Une nouvelle difficulté se présente: AI grandit moins vite que la taille, il en résulte que sur les mâles de petite dimension $\frac{AI}{x}$ est en moyenne plus élevé que sur les femelles de grande taille. Nous ne prendrons que les poissons-rubans mesurant 42 à 52 cm. $\frac{100\ AI}{x}$ est en moyenne de 15·58 pour les mâles (fluctuation probable: 15·2 à 15·9) et de 17·29 pour les femelles (fluctuation probable: 16·7 à 17·7). Les moyennes et leurs fluctuations probables sont donc bien séparées et l'erreur moyenne de la différence des valeurs moyennes est 9. Ce caractère sexuel secondaire est valable.

Le premier rayon de l'anale est en moyenne plus reculé chez la femelle de 7·5 mm. à la taille de 45 cm. et de 8·5 mm. à la taille de 50 cm.

Parmi les poissons-rubans de 42 à 52 cm., mâles et femelles sont ainsi caractérisés (d'après 107 exemplaires):—

| $\frac{100\ AI}{x}$ = | 14 à 15 | 16 | 17 à 18 | 19 |
|---|---|---|---|---|
| ♂ | 100 | 80 | 29 | 0 |
| ♀ | 0 | 19 | 71 | 100 |

La plupart des poissons dont la distance préanale est 0·14 à 0·16 fois la longueur sont des mâles; la plupart de ceux dont cette distance est 0·17 à 0·19 fois la longueur sont des femelles.

La position antérieure de la nageoire anale est plus variable chez les mâles (C : 5·9) que chez les femelles (C : 5·0).

Figure 4. *Cepola rubescens*, e♀t♂ . Le mâle a l'oeil plus petit, la distance préanale plus courte, la nageoire caudale plus longue.

**Callionyme lyre** — On sait déjà que le premier rayon de la première nageoire dorsale a une croissance allométrique majorante chez le mâle, isométrique chez la femelle (G a l l i e n 1934).

Sur les exemplaires de 13 à 25 cm., ce rayon est beaucoup plus long chez le mâle où il peut mesurer 14 à 64 % de la longueur du corps, tandis qu'il n'atteint pas 11 % de la taille dans l'autre sexe.

En outre, à une même taille (groupe d'un centimètre), sa longueur est beaucoup plus variable chez les mâles (où elle peut varier du simple au double) (C = 18) que chez les femelles (C = 6).

## Résumé et Conclusions.

Les caractères externes permettant de distinguer le sexe des cinq espèces de téléostéens étudiés sont résumés dans le tableau ci-dessous (le dimorphisme vertébral de *Zeus faber* L., qui n'est pas un caractère externe, n'y figure pas).

### Moyens pratiques de Détermination du Sexe.

**Pourcentage des mâles.**

*Gadus merlangus:* 1) De 54 à 68 cm. de longueur (taille maxima) : 0 (pas de mâles)

2) De 39·5 à 53 cm. de longueur

$$\frac{100\ AI_1}{x} = \begin{cases} 30{\cdot}8 \text{ à } 31{\cdot}8 : 90\ \% \\ 31{\cdot}9 \text{ à } 32{\cdot}6 : 67 \\ 32{\cdot}7 \text{ à } 33{\cdot}9 : 27 \\ 34{\cdot}0 \text{ à } 35{\cdot}9 : 0 \end{cases}$$

*Zeus faber:* 1) De 47 à 66 cm. de longueur (taille maxima, bouche fermée) : 0 (pas de mâles)

2) Jusqu'à 46 cm. de longueur :
Nombre de rayons aux nageoires :

$$D_1 + D_2 = \begin{cases} 32 \text{ ou } 33 : 90\ \% \\ 34 : 65 \\ 35 : 20 \end{cases} \qquad A_2 = \begin{cases} 21 \text{ ou } 22 : 76\ \% \\ 23 : 38 \\ 24 : 13 \end{cases}$$

3) De 23 à 46 cm. de longueur :

$$\frac{100\ IO}{AI_2} = \begin{cases} 10 \text{ à } 9{\cdot}4 : 100\ \% \\ 9{\cdot}3 \text{ à } 8{\cdot}6 : 67 \\ 8{\cdot}5 \text{ à } 8{\cdot}1 : 47 \\ 8 \text{ à } 6{\cdot}6 : 0 \end{cases}$$

*Mullus barbatus:* 1) De 33 à 38 cm. : moins de 9 %
De 39 à 42 cm. : 0 (pas de mâle)
(Tailles mesurées jusqu'à la ligne joignant les deux pointes de la caudale).

2) De 18 à 34 cm. de longueur :

$$\frac{PO}{O} = \begin{cases} 0{\cdot}7 \text{ à } 0{\cdot}8 : 100\ \% \\ 0{\cdot}9 : 76 \\ 1{\cdot}0 : 51 \\ 1{\cdot}1 \text{ à } 1{\cdot}2 : 20 \\ 1{\cdot}3 \text{ à } 2{\cdot}0 : 0 \end{cases}$$

*Cepola rubescens:* 1) De 46 à 52 cm. : 84 %
A plus de 52 cm. : 100 % (pas de femelle)
(tailles mesurées jusqu'à l'extrémité de la plaque verticale de Cuvier).

2) De 37 à 52 cm. de longueur :

$$\frac{C}{O} = \begin{cases} \text{moins de } 3{\cdot}6 : 0 \\ 3{\cdot}6 \text{ à } 4{\cdot}4 : 32 \\ 4{\cdot}5 \text{ à } 4{\cdot}8 : 80 \\ \text{plus de } 4{\cdot}8 : 100 \end{cases}$$

3) De 42 à 52 cm. de longueur :

$$\frac{100\ AI}{x} = \begin{cases} 19 : 0 \\ 18 \text{ à } 17 : 29 \\ 16 : 80 \\ 15 \text{ à } 14 : 100 \end{cases}$$

*Callionymus lyra:* 1) à partir de 25 cm. de taille : 100 % (pas de femelle).

2) de 13 à 25 cm. de longueur :

$$\frac{100\ lr\ D1}{x} = \begin{cases} 14 \text{ à } 64 : 100 \text{ (pas de femelle)} \\ \text{moins de } 11 : 0 \text{ (femelles)} \end{cases}$$

3) Papille génitale présente, livrée de noces.

x : longueur du poisson
D : nageoire dorsale
A : nageoire anale
AI : distance antérieure à la nageoire anale.
IO : distance interorbitaire.
PO : distance préorbitaire.
O : diamètre de l'oeil.
C : longueur de la nageoire caudale.
lr D1 : longueur du 1er rayon de la dorsale.

Ce tableau n'est valable que pour les populations localisées à l'entrée occidentale de la Manche et près de la côte française de l'Atlantique; par exemple la taille extrême atteinte par les merlans mâles est plus élevée en Islande (57 cm. : Saemundsson, 1925); celle des mâles de *Zeus faber* plus élevée en Mauritanie (50 cm. : Desbrosses 1937) que sur la côte atlantique française.

Cette réserve étant faite, deux constatations se dégagent de nos recherches. On sait déjà que, dans les cas de dimorphisme sexuel dans la taille des nageoires, le mâle a les nageoires les plus longues. Or, nous constatons que les rares espèces de téléostéens dont le mâle a la croissance la plus rapide présentent du dimorphisme dans la longueur des

nageoires : autrement dit, les mâles à croissance rapide ont une croissance majorante de certains rayons de nageoires ou de membranes interradiaires (genres *Mallotus, Cepola, Gobius, Crystallogobius, Callionymus*). Mais la réciproque n'est pas vraie : les mâles à longues nageoires n'ont pas tous une croissance accélérée (genre *Cottus* par exemple).

D'autre part, l'indice de variabilité des caractères sexuels est plus élevé chez le sexe qui grandit le plus vite : ainsi les dimensions du corps sont plus variables d'un individu à l'autre chez les femelles de merlan, Saint-Pierre, rouget-barbet que chez les mâles de ces espèces et chez les mâles de cépole et callionyme que chez les femelles (Desbrosses 1946).

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# Haddock Stocks in the North Sea during 1946.

By

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Aberdeen.

AS a result of scientific investigations carried out in the North Sea by research vessels during the inter-war period, the annual and seasonal fluctuations in the haddock stocks in this region were ascertained, and forecasts made each year of the probable success of the haddock fishery over subsequent years. At the outbreak of war in 1939, these researches ceased, and from then until the end of hostilities nothing is known of the recruitment, movements, rate of mortality, and general biology of the haddock in these waters. It was not until the summer of 1945, when commercial trawlers once more became free to fish large areas within the North Sea, that any knowledge of the recovery of the stocks, subsequent to the period of sustained fishing activity, was gleaned. At this time, observers employed by the Fishery Division of the Scottish Home Department accompanied commercial trawlers, working from Aberdeen, to the fishing grounds off the Scottish east coast in order to collect data regarding the condition of the stocks in this area (1).

In May 1946 the research vessel "Explorer" once more resumed work in the North Sea, and from then until the end of the year carried out extensive surveys of the fish populations on some of the North Sea fishing grounds on the same lines as those during pre-war years. The observations made during this period furnish the data on which this report is based. It must be borne in mind that these researches did not commence until approximately one year after commercial trawling on a larger scale was resumed in the North Sea, and therefore some measure of fishing-out of the older fish, which survived over the war period, will have resulted. However, they provide information as to the success of recruitment of young broods into the post-war stock and by comparison with the 1945 data indicate the effect of partial exploitation by commercial vessels on the fishing-out of the older broods.

During the months May to December, eight voyages were completed which covered an area ranging between latitudes 55°N. and 61°N. and

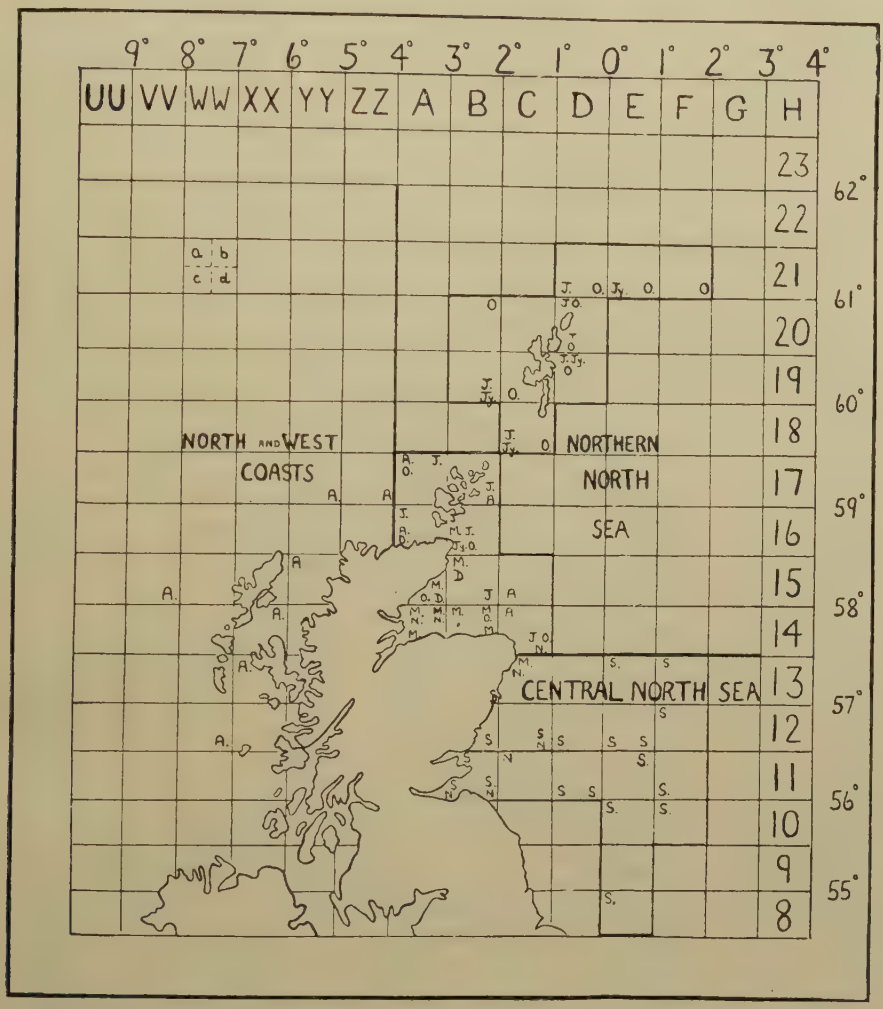


Figure 1. Chart showing Areas Fished by F. R. S. "Explorer" during 1946.
Abbreviations. M = May, J = June, Jy = July, A = August, S = September, O = October, N = November, D = December.

between longitudes 2°E. and 8°W. This area encloses the waters around the Orkneys and Shetlands, the Moray Firth, and central North Sea, and the grounds off the north and west coasts of Scotland. The extent of the area, and the months in which each region was visited, are given in Figure 1. It will be seen that the total area sampled did not cover the deep water grounds of the north-eastern area, from which no records are available. They are not therefore fully representative of the haddock population of the North Sea.

In keeping with the pre-war policy, hauls of one hour's duration were made with the standard otter trawl fitted with a small-meshed cover over the cod-end. All haddock in each haul were measured and scale samples taken for age determination. The scale age determinations were carried out by Mr. W. Main, Experimental Officer, who has performed this branch of the work so consistently and successfully since the haddock investigations were delegated to Scotland in 1921.

**Stock Composition in Areas Sampled.**

The numbers of each age-group and the total catch per 10 hours for each of the five regions fished, namely, the Orkneys, Shetlands, central North Sea, Moray Firth, and west coast grounds, are given in Table 1.

**Table 1. Frequencies of Haddock per 10 Hours on North Sea Fishing Grounds.**

| Year brood | Age | Central North Sea | | Orkneys | Shetlands | North and West Coasts | Moray Firth | | All Areas Combined |
|---|---|---|---|---|---|---|---|---|---|
| | | Sept. | Nov. and Dec. | June to Oct. | June to Oct. | August | May | Oct. to Dec. | |
| 1946 | 0+ | 10 | 24 | 5 | 13 | 1 | — | 17 | 11 |
| 1945 | 1+ | 1657 | 245 | 3182 | 2040 | 499 | 1893 | 593 | 1857 |
| 1944 | 2+ | 415 | 166 | 2328 | 1324 | 117 | 456 | 70 | 983 |
| 1943 | 3+ | 91 | 81 | 423 | 485 | 57 | 74 | 15 | 240 |
| 1942 | 4+ | 28 | 18 | 91 | 161 | 23 | 10 | 1 | 66 |
| 1941 | 5+ | 14 | 4 | 36 | 60 | 31 | 1 | 1 | 28 |
| 1940 | 6+ | 8 | 1 | 42 | 62 | 20 | — | — | 27 |
| 1939 | 7+ | 8 | 1 | 9 | 21 | 2 | — | — | 8 |
| 1938 | 8+ | 9 | 1 | 24 | 24 | 9 | 3 | — | 14 |
| 1937 | 9+ | — | — | — | 1 | — | — | — | 1 |
| 1936 | 10+ | — | — | 1 | 1 | — | — | — | |
| 1935 | 11+ | — | — | 1 | 1 | — | — | — | |
| All Ages | | 2240 | 541 | 6142 | 4193 | 759 | 2437 | 697 | 3235 |

In the Orkney and Shetland and west coast regions sampling was carried out between June and October, during which time no large-scale migration into or away from the areas is likely. The catches from these areas for these months are therefore treated collectively. In the central North Sea and Moray Firth, however, sampling occurred in months when the population may have changed as a result of natural movements of the shoals. They are therefore considered separately. The figures are based on the total number of fish caught in each area. In this way local fluctuations in the numbers in each individual haul, caused by variations in shoal density, are eliminated and the results relate more nearly to the average abundance in each region.

This survey shows that the waters to the north and east of Scotland maintained the densest haddock population during 1946. The numbers

per 10 hours from the Shetland and Orkney areas were, on an average, two and three times greater than those from the Moray Firth and central North Sea grounds. With the exception of the 1946-brood this greater abundance was exemplified by all the age-groups in the catches. The stocks in the Moray Firth agreed more closely with those in the central North Sea than in the adjacent North Sea waters, although the catches contained very few fish of ages greater than four years. The west coast grounds were poorly stocked relative to the northern and eastern areas, but in this region the sampling was too limited for an adequate estimate to be made.

As in previous investigations, the most northerly area sampled yielded the greatest number of the older fish. For those older than two years, the Shetland samples contained more fish than each of the other areas, which agrees with the observed tendency for the haddock to frequent more northerly waters after each spawning migration. Amongst the younger broods, however, the Orkneys proved the main nursery area, the abundance of the 1944-brood in this region being almost twice as great as in the Shetland waters, and over four times more so than in the other areas. This observation is in agreement with the large numbers of this brood caught to the east of the Orkneys by commercial trawlers during 1945. In the Moray Firth and central North Sea the populations were particularly lacking in fish older than three years. In the former these ages appeared in very small numbers in the catches, with the result that the size composition of the stocks here was very much less than in the northern regions. Although these observed differences in abundance of each age-group in the catches must be, in large measure, due to unequal colonization by them of the different regions, it must be pointed out that the most southerly grounds sampled had received the greatest measure of exploitation from commercial vessels after they were declared open to trawlers. Large-scale trawling was resumed in the central North Sea in June 1945, and spread gradually northwards as the grounds were opened. Therefore, this area bore the brunt of the Aberdeen trawling fleet for several months before the deeper waters were extensively fished. In addition the outer region of the Moray Firth was open to commercial trawlers throughout the war years. Thus, greater intensity of fishing-out of the larger fish in the southern regions prior to the time of sampling may account in some measure for the differences in the abundance of these sizes in the trawl catches. The younger broods, however, i. e., those spawned in 1946, 1945, and, to a less extent, that in 1944, had up to the time of sampling failed to contribute largely to commercial catches. Therefore the observed differences in abundance for them must be due to their unequal distribution in the various regions.

In those regions where sampling was carried out during the summer and winter months, the frequencies of each age-group in the latter period had decreased markedly over those in the earlier months. In both instances, however, sampling during the winter months was

restricted to the shallower coastal waters, and did not cover the area sampled earlier in the year. A detailed comparison between the two periods is not, therefore, justified.

The most abundant year-classes in the catches from all the areas sampled were those spawned in 1945 and 1944, which, at the time of sampling, were in their second and third years of life. It was therefore those broods which would largely determine the success of the haddock fishery in the North Sea over subsequent years. In order to determine the relative abundance of those and the other age-groups in the catches, the percentage of each in the total sample from each area has been calculated. These figures are given in Table 2.

**Table 2. Percentage of each Age-Group in "Explorer" Catches during 1946.**

| Year | Age | Central North Sea | | Orkney | Shetland | N. and W. Coasts | Moray Firth | | All Areas Combined |
|---|---|---|---|---|---|---|---|---|---|
| | | Sept. | Nov. and Dec. | June to Oct. | June to Oct. | Aug. | May | Oct. to Dec. | |
| 1946 | 0+ | 0·4 | 4·6 | 0·08 | 0·3 | 0·11 | — | 2·43 | 0·34 |
| 1945 | 1+ | 74·0 | 45·2 | 51·8 | 48·7 | 65·8 | 77·7 | 85·1 | 57·40 |
| 1944 | 2+ | 18·5 | 30·6 | 37·9 | 31·6 | 15·4 | 18·7 | 10·04 | 30·40 |
| 1943 | 3+ | 4·1 | 15·0 | 6·9 | 11·6 | 7·5 | 3·04 | 2·15 | 7·41 |
| 1942 | 4+ | 1·2 | 3·3 | 1·5 | 3·8 | 3·0 | 0·40 | 0·14 | 2·04 |
| 1941 | 5+ | 0·6 | 0·7 | 0·6 | 1·4 | 4·1 | 0·04 | 0·14 | 0·87 |
| 1940 | 6+ | 0·4 | 0·2 | 0·7 | 1·47 | 2·64 | — | — | 0·83 |
| 1939 | 7+ | 0·4 | 0·2 | 0·1 | 0·5 | 0·26 | — | — | 0·25 |
| 1938 | 8+ | 0·4 | 0·2 | 0·4 | 0·57 | 1·19 | 0·12 | — | 0·43 |
| 1937 | 9+ | — | — | — | 0·02 | — | — | — | 0·03 |
| 1936 | 10+ | — | — | 0·01 | 0·02 | — | — | — | |
| 1935 | 11+ | — | — | 0·01 | 0·02 | — | — | — | |

The above figures indicate that of the age-groups present in the catches, those spawned in the years 1945 and 1944 were much more abundant in all the areas than the older broods. These two groups made up approximately nine-tenths of the total catch from the whole area sampled. The 1945 brood, however, had not reached the size wholly retained by the commercial trawl at the time of sampling, so that it contributed little to the commercial fishery in the North Sea.

The 1946-brood, then in its first year of life, was poorly represented in the research vessel's catches from all the areas visited. Individuals first appeared in the catches in June, by which time the larger members had taken to the sea bottom. Its greatest abundance was in the central North Sea catches during the latter months of the year, but even here the frequency was too small for it to be regarded as a successful year brood. It is not possible, however, to gauge the complete survival index of a brood during the first year of life from its appearance in trawl samples, since all individuals do not assume the bottom habitat at the same time. The possibility too of a drift out of the North Sea is being investigated.

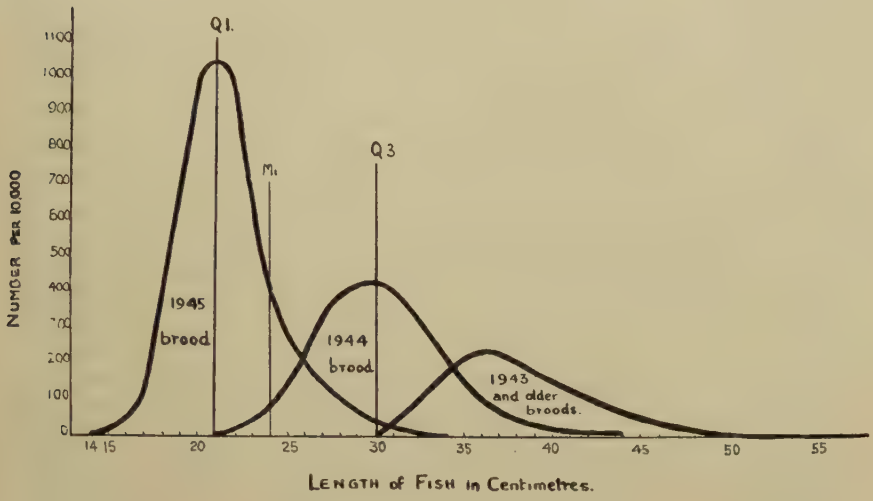


Figure 2. Size Frequencies of Year Broods in "Explorer" Catches during 1946. (Excluding 1946 brood). — Sample Size = 10,000 Fish.
Median (Mi) = 24 cm. Upper Quartile (Q.3) =30 cm. Lower Quartile (Q.1) = 21 cm.

## Size Composition of the Stock.

In the foregoing it has been stated that the two broods spawned in 1945 and 1944 predominated in the catches from all the areas visited during 1946, and that large numbers of them had failed to reach the size when they enter into the market landings. In order to show which sizes were most abundant during this period, the size frequencies for each age-group and the size composition of the total sample have been determined.

Figure 2 gives the frequencies at each centimetre length of the two broods spawned during 1945 and 1944, and the combined size frequencies, for the broods older than these, for the total sample caught by the "Explorer" during 1946. It is evident from Figure 2 and the parameters defining the sample that the haddock population in that part of the North Sea visited during 1946 was composed in large measure of fish which were below marketable size. One half of them were below the minimum landing size of 24 cm. (the minimum regulation then in force) and three-quarters were below 30 centimetres. The broods older than two years ranged in size from 30 centimetres to 67 centimetres, but above 30 centimetres the number per centimetre decreased with increase in length until at 50 centimetres no more than 15 for a sample size of 10,000 fish were present. Fish at this size, therefore, had ceased to figure largely in the total catch.

The sizes recorded above refer to the total sample caught during the period May to December 1946 and include fish before, during, and after

the period of intense summer growth. They therefore represent the mean sizes reached by each brood during the year, being greater than those during May and June, before the yearly growth increment had been added, but less than those at the end of the year's growth. Also, the sample was taken from different areas over which the age compositions have been found to differ. Therefore, in order to determine the differences in the sizes for the different areas, the distributions for each of the five regions have been treated separately. The measures defining these distributions are tabulated below.

**Table 3. Size Composition of Stock from Different Areas.**

| Area | Size Range (cm.) | Median (cm.) | Upper Quartile (cm.) | Lower Quartile (cm.) | Inter-Quartile Range (cm.) | Mean Size of 1945 and 1944 Broods (cm.) |
|---|---|---|---|---|---|---|
| Shetland | 9—61 | 21·5 | 28·5 | 19·5 | 9 | 1945: 19·8<br>1944: 29·2 |
| Orkney | 6—64 | 26 | 31·5 | 22 | 9·5 | 1945: 22·0<br>1944: 29·4 |
| Central North Sea | 11—57 | 26 | 30·5 | 24·5 | 6 | 1945: 24·7<br>1944: 33·3 |
| Moray Firth | 13—62 | 21·5 | 27 | 19·5 | 7·5 | 1945: 19·8<br>1944: 29·3 |
| North and West Coasts | 9—66 | 24 | 31 | 22 | 9 | 1945: 23·9<br>1944: 30·6 |

The above measures show that the sizes comprising the population from the five regions sampled were not the same throughout. The medians of the Shetland and Moray Firth hauls were four centimetres less than those from the Orkney and central North Sea grounds, and two less than that from the north and west coasts. A common feature of all the distributions, however, is that the small sizes predominated. In the Orkney region, which shows the highest value for the upper quartile, three-quarters of the fish were less than 32 centimetres in length, whereas in the Moray Firth this proportion was below 27 centimetres. It is seen also that the mean sizes of the 1945 and 1944-broods, which made up the greater proportion of all the catches, differed from one area to another. Thus, in the Shetland and Moray Firth areas the 1945-brood had reached 19·8 centimetres at the time of sampling, whereas the central North Sea data gave 24·7 centimetres as its size. It is this factor, together with the differences in age composition, which explains the variations in size composition recorded above. The variations in average size of the two young broods are largely due to differences in the months in which each area was surveyed. The Moray Firth sample was caught mainly in May, before the period of summer growth, whereas the central North Sea one was caught in September and later

months, when increases in length had taken place. Similarly, most of the fish from the Shetland area were caught in June and July, whereas around the Orkneys equal quantities were taken before and after the summer growing period.

## Rate of Depletion of Post-War Stocks.

The above study of the age and size compositions of the haddock stocks in the North Sea during 1946 shows that they were composed in large measure of young immature fish, and that the larger and older individuals were present in relatively much smaller numbers. These findings are in contrast with the results obtained from a survey of the catches of commercial vessels during the second half of 1945 (1) when approximately a quarter of the stock was found to consist of fish older than three years. So as to gauge the extent to which the older broods suffered depletion in that area of the North Sea sampled during 1945, a comparison between the age compositions of the stocks during that year and 1946 has been made. Table 4 gives for these years the numbers of each age-group in the average catch per 10 hours fishing from the region extending from the Orkneys in the north to latitude 57°30′N. in the south. The 1945 data are from the catches of commercial vessels fishing from Aberdeen, whereas the 1946 ones are from the catches of the research vessel "Explorer". Adjustments have been made to the 1945 data to make them comparable with the research vessel catches as a result of the difference in fishing power between the Vigneron Dahl and otter trawls used by the commercial trawlers and research vessel respectively.

**Table 4. Relative Abundance of Year Broods in North Sea Catches during 1945 and 1946.**

| Year in which Spawned | 1945 (Commercial Data) | | 1946 (Research Vessel Data) | | % Decrease in Year Broods between 1946 and 1945 |
|---|---|---|---|---|---|
| | Age in Years | Number per 10 hours | Age in Years | Number per 10 hours | |
| 1946 | — | — | 0+ | 11 | — |
| 1945 | 0+ | — | 1+ | 1982 | — |
| 1944 | 1+ | 240 | 2+ | 1093 | [1] |
| 1943 | 2+ | 1235 | 3+ | 215 | 82·5 |
| 1942 | 3+ | 423 | 4+ | 50 | 88·2 |
| 1941 | 4+ | 131 | 5+ | 21 | 84·0 |
| 1940 | 5+ | 153 | 6+ | 20 | 86·9 |
| 1939 | 6+ | 63 | 7+ | 9 | 82·5 |
| 1938 | 7+ | 256 | 8+ | 13 | 94·9 |
| 1937 | 8+ | 2 | 9+ | — | 100·0 |
| 1936 | 9+ | 1 | 10+ | 1 | 0·0 |
| 1935 | 10+ | 1 | 11+ | 1 | 0·0 |
| 1934 | 11+ | 1 | 12+ | — | 100·0 |

[1] This age-group reveals an increase of approximately four-and-a-half times in numerical strength for the two consecutive years.

The above comparison indicates that over eight-tenths of the numbers of fish older than two years had disappeared from the area from which the samples were obtained. In fact, the improvements in stock strength in that region of the North Sea had been largely eliminated in the course of one year's exploitation by commercial vessels. It is not possible to assign this decrease in numbers to the efforts of commercial fishing vessels alone, since not all areas of the North Sea were sampled, and large scale migrations of the older broods out of the region under investigation may have taken place during the course of the year. Also, the area was much more extensively sampled during 1945 than in 1946. However, this area constitutes part of the main feeding area of the haddock during the summer months, and at this time usually sustains its greatest density of this species. The figures are likely therefore to illustrate the order of the effect of large-scale trawling on the stocks on these grounds since the resumption of commercial exploitation.

The results also show that as a consequence of this rapid decline in numbers of the older broods, the haddock fishery in 1946 depended more on recruits from the new broods. These were the one- and two-year-old fish which were growing to the size when they became subject to capture by the commercial trawl. It is seen in Table 4 that the recorded frequencies of these broods, i. e., those spawned in 1945 and 1944, appeared in larger numbers in the 1946 catches than in the 1945 ones. This is due to a difference in the sampling apparatus used in the two surveys. No small-meshed cover on the cod-end of the trawl was used by the commercial vessels, with the result that fish small enough to escape through the meshes were not retained in their true relative abundance. For the youngest age-group, the trawl data cannot be taken as a measure of its true abundance in the sea. The first few months of the haddock's life are spent in a pelagic or semi-pelagic state, when it will not appear in trawl catches, and not until all members of that brood have taken up the bottom habitat will the trawl catches be representative of its true abundance. Not all the individuals of the brood take to the bottom at the same time, and even by the end of its first summer this youngest brood may not be truly demersal. Thus, the second year frequencies for any one brood are usually greater than the first year ones.

## Magnitude of Recruitment to Post-War Stock.

As a result of yearly observations of the numerical strength of the second year frequencies of the haddock in the North Sea during the inter-war period, a system of forecasting the success of the fishery over subsequent years was evolved. According to Thompson (2) the observed fluctuations in the survival of each year's brood were reflected in the yields of commercial vessels over subsequent years. Raitt (3) records the second year frequencies for the period 1918—1936. These records have been extended to include the broods spawned in 1937, 1938, 1944, and 1945. Data for the period 1939 to 1943, as already

explained, are not available. The second year frequencies from 1918 to 1945 are tabulated below.

**Table 5. Frequencies of Haddock in their Second Year: 1918 to 1945[1]).**

| Year-Class | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 |
|---|---|---|---|---|---|---|---|---|
| Frequencies per 10 Hrs. | 831 | 1056 | 2183 | 215 | 49 | 2806 | 1192 | 964 |
| Year-Class | 1926 | 1927 | 1928 | 1929 | 1930 | 1931 | 1932 | 1933 |
| Frequencies per 10 Hrs. | 1550 | 308 | 3511 | 662 | 303 | 1835 | 318 | 699 |
| Year-Class | 1934 | 1935 | 1936 | 1937 | 1938 | 1944 | 1945 | |
| Frequencies per 10 Hrs. | 250 | 2094 | 265 | 195 | 677 | 983 | 1857 | |

[1]) (a) 1918—1936 — after R a i t t.
(b) 1938 frequencies based on researches from May to August 1939.
(c) 1944-brood figures are *3rd* year frequencies from research vessel data during 1946.

R a i t t (3) also gives, in graphical form, the fluctuations in initial recruitment for the years 1918 to 1936 based on that of 1923 which was rated at 10. This graph has been extended to include the 1937 to 1945 data and is presented in Figure 3.

On the basis of the above records, it is seen that the 1945-brood came into the category of good recruitment. Only four more abundant

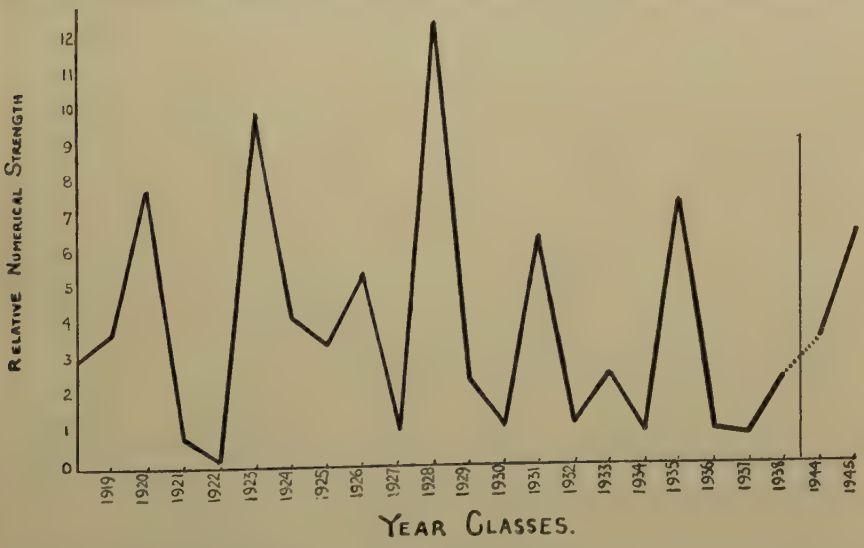


Figure 3.
Fluctuations in Initial Recruitment of North Sea Haddock Stock 1918—1945.
(1918—1936 figures after Raitt)

years were experienced during the period since investigations commenced. The quoted figure for the 1944-brood is an underestimate of its actual initial abundance, as by the time it was sampled in 1946 the larger individuals of the brood had become subject to capture by commercial vessels. Despite this, its third year frequency was above the average for broods of intermediate numerical strength. It may be said, therefore, that the recruitment of young individuals to the post-war haddock stocks was well above the average for the inter-war period. It must be borne in mind, however, that sampling during 1946 was on a smaller scale than that carried out up to 1939, and the area covered in the researches did not extend to all fishable regions of the North Sea.

Although, as stated earlier, trawl data may underestimate the true frequencies of haddock in their first year of life, some indication of their survival may be gleaned from these figures. On this basis it may be stated that the 1946-brood was poorly represented in that part of the North Sea sampled. The average frequency per 10 hours of this brood was 11, taken from the month when they first appeared in the trawl catches, and this is little more than 4 % of the frequency of the 1938-brood in its first year of life. This brood, according to its second year frequency, proved to be of no more than intermediate numerical strength. Records collected during 1947, up to the time of writing, support this observation on the poverty of recruitment from the 1946-brood.

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# On the Breeding Places and Abundance of the Red Fish (*Sebastes*) in the North Atlantic.

By

**Å. Vedel Tåning.**

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THE development within recent years of the sea fisheries carried on from the north-west European ports has shown clearly that it would be of significant importance if new reserves could be tapped in the sea to ease the pressure of the fishery on the fish stocks which are now threatened by overfishing. The following investigation has thus been undertaken from the point of view that the first thing of importance is to ascertain the extent or limits of all natural reserves of fish-food within all marine areas of interest to northwest European fisheries. As is wellknown, we reckon generally that outside the continental shelf, out over depths greater than 500—1000 metres, we do not find economically important species apart from more or less chance shoals of herring, cod, tunny, etc. in migration from one coastal area to another. In the northern Atlantic, however, we have at least one large, edible, and important species, which is an exception to the rule, namely, the Red Fish or Norway Haddock.

During our investigations in northern waters, extending over a score of years, we have paid attention to the biology of the Red Fish, its distribution and development etc., and in the last twelve years we have taken the opportunity of determining the temperature needs, and the like, of the species at the different stages of development, as also the quantitative distribution of the young of the two known species and of the adult fish on the banks, the occurrence, possibly, of different races, and so on. This investigation has come as a natural consequence of the fact that the species has in recent times proved to be one of the most important food-fishes in northern waters, since the people of central Europe have begun to use it in the form of filets. Further, because of its rich oil-content, it has been used especially in the production of oil and fish meal. The oil of the Red Fish has been found to be extremely rich

in vitamins[1]). In 1938 the species had reached so high in the scale of food-fishes that the quantities, 105 thousand tons, in that year brought it up to the sixth place among the fish taken; the catches came mainly from Icelandic and Norwegian waters. Interest in the Red Fish spread to other places, and the possibility was considered of developing a fishery at the Faroes. Our investigations therefore assumed a more definite form in the years 1937—39, and we endeavoured to determine the real extent of the area in which the Red Fish spawns in the northern Atlantic.

During the cruises of the "Dana" shortly after the first world-war we succeeded, by help of the pigmentation, in distinguishing with certainty the tiny fry of the large Red Fish from that of the small species. This is a more southerly form, more closely bound to the coastal areas and neighbouring banks, being found chiefly inside 200—300 metres, whereas the large species is a deep-water form, living mostly pelagically out in the open sea; it would appear as far as we know chiefly at depths of 200 to 500 metres, but also deeper.

Various observers had earlier noted that there were two forms in European waters, but some have not been inclined to regard them as separate species, considering them as only races or varieties. The large Red Fish, *Sebastes marinus* (Linné 1758) which can reach a length of almost 1 m., is the principal form in the fishery on the European side of the Atlantic, whereas the small form, *Sebastes viviparus* Krøyer 1845, which is usually under 36 cm. in length, is of little value in Europe. A third, rather small, form has since about 1933 gradually become of great importance on the American side of the Atlantic[2]). The reason why a specific distinction between the large and the small Red Fish of European waters was doubted arose from the fact that the characters used showed overlapping and that the life-histories were not sufficiently known. A closer examination has proved, however, that certain characters differentiate quite clearly, without any overlapping, the two species from each other (e. g., the number of scales below the lateral line: *S. marinus* ca. 58, *S. viviparus* ca. 42) and that the modes of life and the whole life-histories are widely different. They are both viviparous obviously in contrast to the allied scorpænoid fish, *Helicolenus dactylopterus* (Delaroche 1809) which is also found in northern Europe, though it is rather rare, being a more southerly form.

During the internationally organized investigation of the Gulf Stream in 1938, in which Denmark's part included the area west of the British Isles, west of the Faroes and south of Iceland, it was found pos-

[1]) The vitamin content in the oil of the whole fish is reported to be on a level with that of cod-liver oil; oil from its liver has a much higher content of vitamins A and D, especially A, than cod-liver oil.

[2]) In 1946 the landings (about 90 thousand tons) were higher than those of cod and haddock, thus bringing the species up to number 6 in the scale of all food-fishes also from this area, from Cape Cod to Nova Scotia. In 1933 the fishery only yielded about 130 tons. The American Rosefish seems to be distinct from the two European species.

sible from the Danish side also to study the occurrence of the fry of the Red Fish. From this, as well as from earlier investigations, it became clear that the large Red Fish must be linked to temperatures round 3° to 8° C. at its spawning period. From this it could be inferred that its spawning area in the northern Atlantic waters was probably much greater than had previously been supposed. It was known that quantities of the fry occurred to the south and west of Iceland, west of the Faroes, off south-east Greenland and, more rarely, off south-west Greenland, to which according to A d. S. J e n s e n (1922) the fry reach with the current from Denmark Strait round Cape Farewell (this has as far as we know proved correct for certain periods of years). Further, the fry had been known from various places along the Norwegian coast and somewhat out in the Norwegian Sea off Norway. Lastly, fry had also been taken in the Newfoundland area and southwards from there; but it soon became clear to me that the form in the American region was not the large Red Fish *(Sebastes marinus)* but in some characters more closely allied to the small Red Fish *(Sebastes viviparus)* (the Red Fish or Norway Haddock is usually called Rosefish in America and seems to have been first described there as a separate species, *Sebastes fasciatus,* by S t o r e r in 1854).

It was thus a matter of delimiting the area in which the large species spawns, so far as this could be done by one single country. It was not possible, however, to include in the investigation the Norwegian area, where a large portion of the North Atlantic spawning stock occurs, right from southern Norway up to the Barents Sea and south-west of Bear Island.

In the period just after the war it was not thought advisable to let the "Dana" work more than was absolutely necessary in the shallow water areas still more or less infested with mines; consequently, the deeper waters were preferred for the work of the first years. Further, several questions concerning some of the food-fishes which spawn in deep water west of northern Europe or which are carried by the currents from the Icelandic area over to Greenland, had to be investigated more closely than was possible before the war. Since also a large part of the Gulf Stream in its course from the American side over to Europe had so far remained wholly or partly uninvestigated, it was proposed to carry out a combined biological-hydrographic study of the large region of the sea lying west and south of the Faroes—Iceland region, the Denmark Strait and southern Greenland, southwards to the warm water (northern edge of the Gulf Stream) and westwards to the cold water (Labrador Current). The cruise was intended to begin in 1946, but strikes etc. delayed the ship's overhaul after the war to such an extent that the season for an oceanic cruise was lost. The cruise was then postponed until 1947 and was made in the period 14th June till 8th July in conjunction with the fisheries investigations at the Faroes.

It may briefly be noted here that the original incentive to the cruise of 1947 was some important discoveries made during a cruise in June

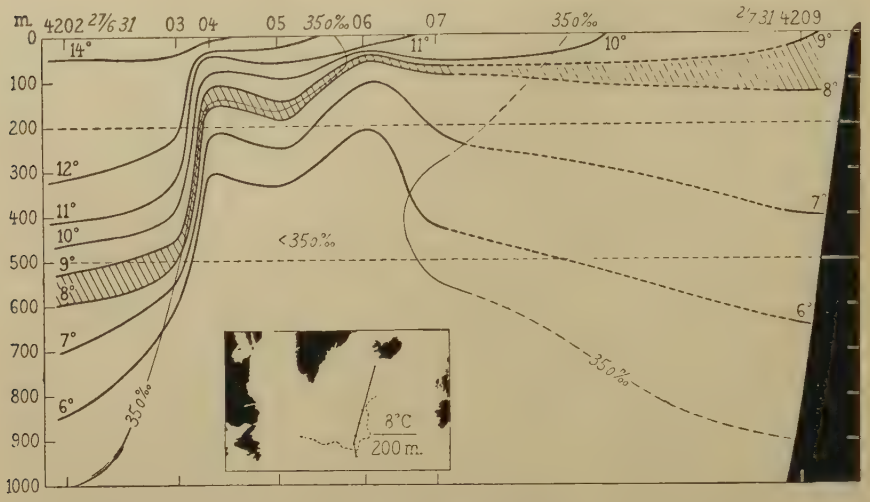


Fig. 1. Hydrographic section across the northern border of the Gulf Stream from about 47½°N., 28½°W. to Iceland ("Dana" 1931). The area with temperatures of 8° to 9°C. is shown hatched. The inset shows the position of the section and the 8° curve at a depth of 200 metres. (This and following sections were prepared by Mr. F. Hermann).

1931, from Madeira and the Azores to Iceland. The object of that cruise was to obtain a quantitative expression of the numbers of eel larvae *(Leptocephalus brevirostris)* about 1 year old in an area which lies between the spawning place and the regions where the metamorphosis to elvers takes place. As we were going north, in the period 27th June to 1st July, in about 50°N., 31°W., we could not but remark upon the striking change in temperature and salinity along the border between the Gulf Stream and the colder boreal waters to the north, the animal life in these water-masses being also extremely different. Whilst to the south we had temperatures of 8°—9° C. in depths below 500 metres, these temperatures about 60 nautical miles farther north had risen to depths of 150—200 metres (see Fig. 1); and at one of the stations (St. 4206) inside the border line (53°38′N., 29°41′W.) we caught an adult male Red Fish of 48 cm. in length at a depth of about 300 metres. This capture together with the rest of the animal life (compared with that in the Gulf Stream) showed that we had to deal with an entirely different community of animals[1]), and also that the Red Fish after spawning was to be found right out in the open ocean far from the coastal banks, where the adults are best known. The same experience with regard to adult Red Fish living pelagically had already been made out in the Norwegian Sea several years ago; there the Red Fish had been taken on floating lines at a depth of 200—400 metres over great depths. But it was the first time that the large Red Fish *(Sebastes marinus)* had been taken so far to the south as well as out in the open ocean.

[1]) a pelagic high boreal community.

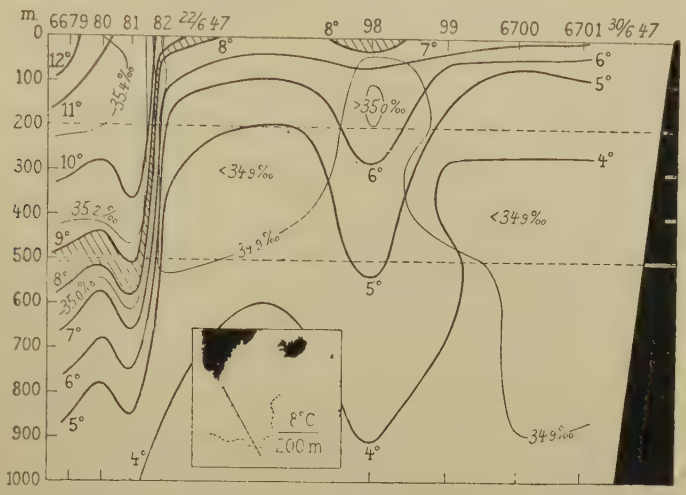


Fig. 2. Hydrographic section across the northern border of the Gulf Stream from about 49°N., 31° W. to Cape Farewell, Greenland ("Dana" 1947). Otherwise as in Fig. 1.

A second illuminating fact made use of in planning the investigations came from the "Dana" cruise 1938 during the Gulf Stream survey, when it appeared that the same combination as just mentioned of the temperatures was necessary before the young of the Red Fish were obtained, as we went northwards along meridian of 20°W., west of Ireland. Only when the water-masses with temperatures around 8—9° were no longer found in the depths below 500 metres but began to rise up to depths about 200 metres or even less, was it possible to catch the fry of the large Red Fish in the nets (this happened on the section along 20°W. in about 60°N.).

Lastly, we had found in the course of many years' investigations off northern Iceland, and East and West Greenland, that the tiny fry of the Red Fish were not obtained unless temperatures of over ca. 3—4°C. occurred out over deep water in depths about 200—500 metres, which seem to be the preferred depths of the Red Fish at most places[1]).

From these facts we were obliged to conclude that the boundary of the spawning area of the large Red Fish towards the warm Atlantic water was to be found where the boreal mixed water of 8°—9°C. did not lie essentially below a depth of 200 metres, but in the main higher up, and further that the cold water of less than ca. 3°—4°C. near the paths of the Arctic currents should not occupy the area in depths of about 200 to 500 metres (cf. Figs. 1—4).

During the 1947 cruise it was actually proved that *when* these requirements were fulfilled, the fry of the large Red Fish were to be found *everywhere,* even so far to the south as about 50°N.; once only we found 1 postlarva of the species just outside this boundary (along with eel larvae, *Leptocephalus brevirostris,* which is usually not found within this boundary before metamorphosis has begun); but the mixing

1) There are certain exceptions from this in the boundary areas, especially to the north.

of the water-masses naturally takes place to a large extent, especially in the surface layers just where the Gulf Stream and the boreal mixed water meet sharply in a wall and where presumably organisms from the one water-mass may often be carried over into the other. Along the northern side of the Gulf Stream (about 50°—51°N.) from about 28°W. to a position just north of Flemish Cap (east of Newfoundland Bank) we cruised in the summer of 1947 steadily back and forth between the cold and warm water, to find the conditions quite in agreement with the assumptions. The course of the Gulf Stream, however, from ca. 50°N. and northwards along 28°W. approximately, as far almost as the latitude of Rockall, is still not known with certainty. The work of this one year has naturally been insufficient to enable us to determine full details and probable fluctuations from year to year of the course of the Stream, but the Figures 1—4 give the main features of the results obtained, supplemented with information from the few scattered observations from earlier expeditions ("Armauer Hansen" under the direction of Helland-Hansen, the schooner "Margrethe" sent out by Johs. Schmidt in 1913, and a few more). A very surprising result was to find several southern deep-water fish and also some surface-living young fish of southern origin in the area north of Flemish Cap, where the Gulf Stream and Labrador Current struggle for mastery; these forms belong to the Sargasso Sea and the warmer areas under the influence of the Gulf Stream. In this area north of Flemish Cap we found also the young of the American Rosefish, which may be considered to have been carried out from Flemish Cap or other parts of the Newfoundland Banks area, with the result that here, just as in the case of the bank area south of Iceland, we could obtain the young of two Red Fish species in the same haul. In this area we also found the eggs of the Halibut, which had previously not been recorded from the American side of the Atlantic.

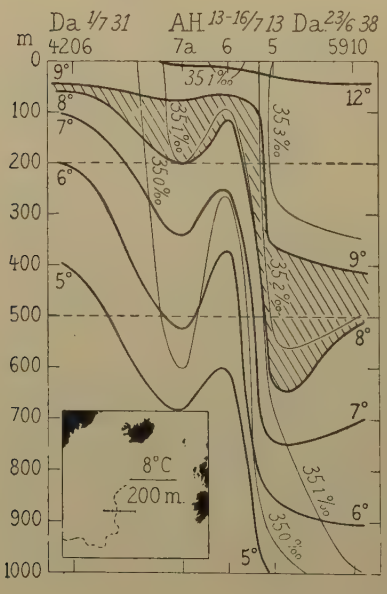


Fig. 3. Hydrographic section across the western border of the Gulf Stream in about 54°N., 29°W. (Various stations from "Armauer Hansen" and "Dana"). Otherwise as in Fig. 1.

It was not possible in 1947 to continue the investigations along the boundary between the Labrador Current and the mixed-water area; but as the fry of the Red Fish is not known from the western side of Davis Strait, probably not west of the middle of the great deep reaching

northward to the submarine ridge at Holsteinsborg, the western boundary of the spawning area south of Davis Strait[1]) will certainly lie at a similar distance from the Labrador Current as in Davis Strait, probably where the water at 200—500 metres depth has a temperature below ca. 3°—4°C. and the salinity is low (< 34·8?). The boundary will, however, have to be determined by future investigations; presumably the fry of the large Red Fish will be found carried by currents

Fig. 4. Approximate breeding area of the large Red Fish (*Sebastes marinus* L.).

into the surface layers over a part of the Labrador Current, in the same way as the fry can be found in the surface waters off East Greenland some little distance in over the East Greenland polar current.

The chart (Fig. 4) shows the approximate spawning area of the large Red Fish in the North Atlantic south of the submarine ridge Shetland — Faroes — Iceland — Greenland — Baffins Land; the area eastward to the Faroes and Shetland and northeastwards along Norway and presumably some distance out into the Norwegian Sea, can as yet only be delimited from a consideration of the temperature conditions owing to lack of sufficient records of postlarvæ; the boundaries of the chart are therefore here to a certain degree drawn from the temperature curves, but should naturally be verified by a search for the young fry.

On the whole the large Red Fish quite clearly requires temperatures between 3—4° and 8—8·5°C. in its spawning area, whilst the temperature requirements of the small species lie a few degrees higher.

[1]) very little spawning takes place in Davis Strait proper.

Non-spawning individuals may, however, be met with at both lower and higher temperatures. The salinity requirements seem to lie around 34·8 —35·3 ‰, especially about 34·9—35·2 ‰.

In a part of the large spawning area south of the submarine ridge between the Atlantic proper and the Norwegian Sea the conditions at first were not so easily understood; it was a question of the amount of spawning in the large deep bight, which northwestward of Rockall, Lousy, and Bill Bailey's Banks and the Faroes projects eastwards south-east of the Reykjanes ridge and south of Iceland. In 1903 Schmidt had found in this area large quantities of the young of the Red Fish, though not so very large quantities as he found in Denmark Strait west

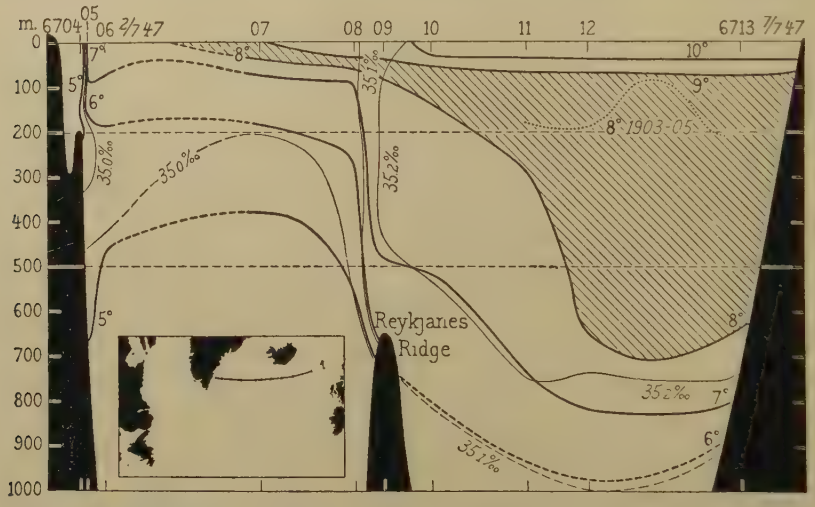


Fig. 5. Hydrographic section from East Greenland to the Faroes across the Reykjanes Ridge ("Dana" 1947; see inset). ····· Curve of 8° from the years 1903—05. Otherwise as in Fig. 1.

of Iceland (where a maximum of about 4000 specimens of the young fry could be taken in 10 minutes with the Petersen young-fish trawl, which is a more effective fishing instrument than the 2-metre stramin nets now used, though the latter are the more easily handled). In later years (after 1930) when we had the opportunity to fish for pelagic fry in this area and in Denmark Strait, we found similar quantities in the latter, but much less in the large bight south of Iceland, where the number per haul was always rather low except in the western part nearest the Reykjanes ridge. The explanation appeared at once when some scattered hydrographical observations from the years 1903—05 were examined; they yielded some idea of the course followed by the temperature curves of 8° and 9° then and now. Unfortunately, there are but few observations for these and following years, yet they show clearly that water with temperatures over 8° in the oceanic part of this area was only found down to about 200 metres, even at certain places to

a depth of about 50 metres (see Fig. 5); here therefore at that time the conditions were ideal for the spawning Red Fish. The information derived from hydrographic sections from more recent years (1938 and 1947) shows a great contrast; *now* the eastern part of this large bight is almost entirely filled with water-masses having temperatures between *8° and 9° from a depth of about 50—100 metres right down to 600—700 metres;* and the change in conditions is thus so great that the Red Fish has certainly retreated to a great extent from this area, formerly much more frequented. It is of extreme interest that this storage of warmer water in this large bight has taken place at the same time as a movement of higher temperatures *in the surface layers* towards the north in the present warm period, which so clearly rules over the northern hemisphere in our days. Observations from 1913 ("Margrethe") show similar conditions as in 1903—05; possibly the conditions were still somewhat similar in 1925, but we cannot say with certainty when the change occurred owing to lack of observations. It will, however, be of great interest to follow these conditions more closely in the future, since in this way we may discover whether the present warm period is changing in one or other direction and when this occurs.

Lastly a few words may be said here regarding *the quantities of fry* captured during certain of the earlier cruises and that of 1947. As already mentioned, S c h m i d t was able to take 3795 specimens of tiny fry in 10 minutes (maximal catch) off western Iceland (off southern Iceland the maximal catch was 365 specimens in 10 minutes). Similar quantities (due regard being taken of the fishing capacity of the apparatus) were found in recent years in Denmark Strait[1]) and at Reykjanes ridge. Here obviously there must be a special accumulation of Red Fish. Some of the largest commercial trawl-catches of the adult fish have been made off western and northwestern Iceland on the banks where large quantities of Red Fish have, so to speak, been stranded in depths corresponding to those in which they live out in the open ocean, and it is reasonable to consider this accumulation as caused by the prevailing currents. Something similar evidently takes place as a result of the currents along the ridge between the Faroes and Iceland, but the Red Fish spawns very little here; it would seem that when spawning time approaches, they move away from this area, since the pelagic fry have not hitherto been found here in reasonable proportion to the trawled quantities of adult fish. How far the mature Red Fish undertake greater seasonal migrations within its huge area of distribution is, however, not yet known. It is possible that only the portion of the stock which during the growth period has reached places unfavourable for reproduction undertakes migrations from there to the nearest favourable areas for reproduction, whilst the remainder do not migrate

1) Large quantities of young fish, spawned west of Iceland and in certain parts of Denmark Strait, are carried by the current along East Greenland, round Cape Farewell, and farther along the west side of South Greenland; the same route seems to be followed by numbers of cod and halibut fry from Iceland to West Greenland.

to any great extent; but we know nothing about this. Nor do we know in detail whether there is a seasonal accumulation of Red Fish in the open ocean in certain areas owing to special conditions of food or of temperature and salinity. An extremely large part of the whole spawning area of the Red Fish lies, however, more to the south and west than the

Fig. 6. Fry of large Red Fish (*Sebastes marinus* L.) from ½ hour's haul with the 2-metre stramin-net about 300 miles southeastward of Cape Farewell ("Dana" station 6699, 56°02·5′N., 38°43′W., 29/6/1947; 1072 specimens, size of fry 9—21 mm., average 14·7 mm.). Photo E. Bertelsen.

places where hitherto fishing experiments have been made in search of the pelagic fry with suitable apparatus and in the depths where the fry are specially found, namely, in the uppermost 50 metres. In the central portion of this extensive area but few stations were taken in 1947, as the chief aim was to discover the boundaries where the fry of the Red Fish ceased to occur. Nevertheless, up to 1100 specimens were taken in half an hour's haul with the 2-metre stramin net in the more central area mentioned south of Denmark Strait (see Fig. 6).

To gain some idea of the abundance of the large Red Fish we may try to estimate how many pelagic fry were taken in June—July 1947 per net per hour. Making this calculation for the whole area investigated in June—July of this year, when the young are no longer quite tiny (ca. 7—10 mm.) but have reached an average size of ca. 12—14 mm. (from 7—22 mm.) and are thus able to escape the fishing gear to some

extent, and in spite of the fact that the major portion of our fishing was carried on in the peripheral and more thinly populated part of the spawning area, we obtain nevertheless an average of 200 specimens in an hour's haul with the 2-metre net. This gives as a minimum far over half a million specimens of fry per $km^2$. (and this calculation only refers to a distribution from the surface down to a depth of 50 metres; probably the young also occur at somewhat greater depths). Since the area in which the young were taken, or may be assumed to occur, extends to over $2\frac{1}{2}$ million $km^2$., we thus reach astronomical figures for the catchable quantities of young in the sea at the season when the fishery was carried out in 1947, thus at a period as noted when the young are already capable of escaping the fishing gear.

Any one who has taken the fry of cod or herring in the restricted breeding areas of these two species on the coastal banks of Iceland or in the North Sea will feel convinced, on discovering these large quantities of Red Fish fry over such immense stretches of the ocean, that the Red Fish is present in the ocean in far greater quantities than the two species mentioned, which are the principal fish in the fisheries of northern Europe, together constituting ca. 65 % of all the fish landed in northern Europe in the years 1934—38.

There is no doubt, therefore, that the Red Fish will form a reserve to the fisheries when overfishing intensifies again; without doubt also the right methods for exploiting this wealth will be found, not only the smaller quantities on the off-shore banks already well fished with the trawl before the war, but also the larger numbers in the open ocean where human skill will certainly find some way of overcoming the difficulties in the way of carrying on a rational fishery. So far none of the fairly large, numerous and valuable animals on our globe have escaped pursuit by man sooner or later, however great the technical difficulties for their capture may have been.

# The Use of Nematodes as Food for Larval Fish.

By

**Anton Fr. Bruun.**

THE raising of fish larvae in great numbers is closely connected with the problem of mass producing a suitable food. For many years this problem has been fairly well solved as regards freshwater fishes by means of artificial cultures of infusorians; we are here disregarding all such species of fish as salmon or trout, which are able to eat macroscopic animals like *Daphnia*, etc. But even when rearing small fish larvae, especially many species of tropical origin, difficulties often arise during the period when the small fishes are too big to be satisfied with infusorians or rotifers, but too small to eat even the youngest stages of *Daphnia*. For smaller numbers of such tiny fish larvae one can generally use nauplii of various freshwater copepods like *Cyclops* or *Diaptomus*, which can be caught in great numbers in nature. The procedure is usually to catch egg-bearing females and keep them until the eggs have hatched, the nauplii afterwards being separated by sifting through fine-silk nets. This method is still widely used amongst those who keep tropical fishes in aquariums as a hobby.

A very important step forward was taken in 1932, when at the suggestion of R o l f L. B o l i n of Hopkins Marine Station, California, the nauplii of *Artemia salina* were utilized; they are now used in enormous quantities, especially in America, where the sale of *Artemia* eggs has almost become a trade, and *Artemia nauplii* and older stages have become one of the standard foods for raising many species of tropical fishes kept indoors in aquariums in colder latitudes.

*Artemia* could also be, and indeed have been, used for larvae of marine fishes, thus opening the way to the mass production of young saltwater fishes to a size at which they may be liberated in the sea with

a good prospect of surviving, having left the most dangerous pelagic period behind. It is sufficient here only to mention Rollefsen's name and magnificent achievements in this direction.

It might be useful, however, to have additional sources of food at hand especially of even smaller size than the nauplii of *Artemia*. It might well be worth while to try to make pure mass-cultures of some species of marine infusorians and have them tried out on fish larvae. Meanwhile another source is here suggested because it has been used with great success by keepers of tropical fishes in Denmark for some twenty years, and is now widely used in many countries. It is a nematode, *Anguillula aceti* Ehrenberg. Larsen (1941) has given an historical account of the use of nematodes as the initial food for newly hatched tropical fishes. According to him the first mention of this in Danish literature is from 1925, when Weichel in "Stuekultur, Naturen og Hjemmet" described how he used "some almost microscopical worms (young ones of Enchytreans)" in feeding his young characins of the species *Pristella riddleyi* (Meek). Weichel, being an amateur, did not know, obviously, that the microscopic worms could not be the young of his *Enchytraeus albidus* Henle, which he cultivated for his tropical pets; but this error is easily understood when reading, in an article from the same year, "A good food item for the fry of aquarium fishes", his description of how to produce masses of the microscopic worms. He recommended mixing a good portion of porridge with some milk, pouring this mixture over the surface of the earth of a culture of *Enchytraeus* in a wooden box, and placing a plate of glass directly over the porridge. This procedure permitted a living mass of very small worms to be scraped from the under side of the plate 6 to 8 days later. Every year since these "micro-worms", as they were later called, have been mentioned in Danish aquarists' journals and have been used with success in raising fry of many species, e. g., of the genera: *Aphyocypris, Barbus, Betta, Cichlasoma, Colisa, Cyprinodon, Dermogenys, Hemichromis, Hemigrammus, Hyphessobrycon, Melanotaenia, Nannostomus, Trichogaster,* and several others.

The nematode has been studied by various scientists, *inter alia,* by Bennike (1941), who identified it as *Anguillula silusiae* De Man, and there seems to be general agreement amongst the specialists that the species from Danish cultures corresponds very well vith De Man's species. A Danish specialist, Mr. Christian Overgaard, M. Sc., has experimented with different media for the culture. He is of opinion (verbal information to the author) that it is impossible to maintain any specific distinction between *Anguillula silusiae* De Man and the well known *A. aceti* Ehrenberg; hence the latter name appears to be the appropriate one.

As regards the characteristics of *Anguillula aceti,* Bennike (l. c.) gives some details of the species as he found them in Danish aquarists' cultures. It is a typical, small, free-living nematode, the largest females measuring about 2·56 mm. and the largest males about 1·9 mm., while

the diameter of the cylindrical body is about 0·05 to 0·08 mm. (see Figure 1). It is viviparous; up to 15 young ones may be counted in a pregnant female. This viviparity is very important, because it means that when feeding fish larvae from a culture there will always be present much smaller specimens than those of the maximum measurements given above.

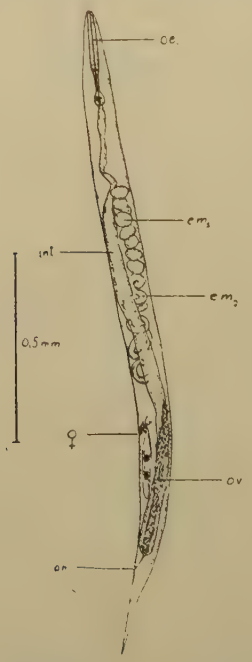


Fig. 1. *Anguillula aceti*, female, schematically. ov. ovary; em1, younger, and em2, older stages of young ones in the uterus; oe, oesophagus; int, intestine; q, genital opening; a, anus. (From B e n n i k e 1941).

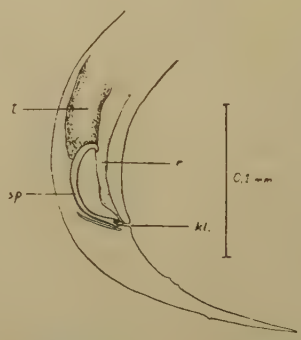


Fig. 2. *Anguillula aceti*, posterior part of male. t, testis; sp, spicule; r, rectum; kl, cloaca. (From B e n n i k e 1941).

For culture, most aquarists keep the nematodes in wooden boxes half filled with mould kept well moistened; as already mentioned above such a culture is fed with a porridge to which is added some milk. The cultures must be kept closed to avoid invasion of different species of flies, the larvae of which may entirely spoil the culture. If the culture is not to be used for some time, it can be left to dry up, and the nematodes will form resting stages, which will soon give rise to a new culture when moisture and food is again supplied.

Another successful method of culture is to place some food in a Petri dish, add some drops of a nematode culture, and cover the dish. At room temperature the porridge will be transformed into a living mass of nematodes in a short time, some 6 to 10 days. It seems that these

cultures flourish better if new ones are started at fairly short intervals, instead of using the same dishes again and again.

Whatever method is used, it is important to have the culture moist, without being really fluid; furthermore, not too much food must be given at one time, so that it is not transformed into a culture of fungi.

In using *Anguillula* as food for fish fry, the nematodes may be added to the aquarium simply by stirring them gently into the water, or they may be placed in a small sieve of fine silk, hung at the surface, through which they will spread. This nematode has several special advantages. It can stand a very wide range of hydrogen-ion concentration, lives for a long time in salt water, and indefinitely in fresh water. It is an active swimmer, an unusual feature amongst nematodes, which makes it easily seen by the young fish. So far it has been used in a very few experiments with plaice and flounder larvae, though without success; but since simultaneous experiments using *Artemia* nauplii were also unsuccessful it is believed that the failure must lie in the method of feeding, especially poor light conditions. The success attained with many freshwater species can undoubtedly be repeated with saltwater fishes as well.

Although *Anguillula* has not been tried as food for invertebrates, it seems very likely that it would be eaten by various animals. This is indicated by some observations made by Nybelin (1931). In his study of the life-history of "*Filaria*" *sanguinea* Rudolphi he made the very interesting observation that *Cyclops* become infested by "*Filaria*" larvae *by eating them*, and not by the "*Filaria*" larvae invading the *Cyclops* through the cuticle. It might therefore be worth while to try *Anguillula* as a food for such invertebrates, which have hitherto been difficult or impossible to keep in aquariums because of lack of suitable microscopic food.

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Larsen, Ove 1941: "Er Mikroorm en dansk Opdagelse?" Akvarie-Vennen 1941, pp. 2—4. Helsingør.

Nybelin, O. 1931: "Zur Entwicklungsgeschichte von "*Filaria*" *sanguinea* Rudolphi nebst Bemerkungen über verwandte Arten, insbesondere über den Medinawurm." Zentralbl. f. Bakteriologie, Parasitenkunde und Infektionskrankheiten. I Abt. Originale, 1931, Bd. 121, pp. 58—64. Jena.

No attempt has been made to collect all the numerous references to *Anguillula* to be found scattered, for instance, in American, Danish, English, and Swedish aquarists' journals.

# A Review of the Results of Salmon Marking in the Baltic Region.

By

**T. H. Järvi.**

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IT has been known since ancient times that salmon travel very long distances before they ascend the northern rivers of Finland and Sweden. Every now and then a salmon with a hook, unfamiliar to the local inhabitants, caught in its jaw or throat has been landed. Soon after 1880 Malmgren noted that the majority of the various types of hooks found were those used on the coasts of Pomerania and East Prussia, and others were from round Bornholm and the coast of southern Sweden, which proves that the salmon carrying these hooks came from the southern areas of the Baltic Sea. Willer and Quednau have also collected similar information in recent times and have used it to study the migration of salmon in the southern parts of the Baltic Sea. In some instances very precise information may be obtained, for some of the salmon have carried, not only the hook, but also a piece of line with the sinker and other devices. Since fishermen fairly commonly mark their sinkers with their initials or other means of identification, the locality in which the salmon broke free can be determined accurately. Two examples follow. In 1931, in Seivästö, in the eastern area of the Gulf of Finland, a nine-and-a-half kilogramme salmon carrying a hook, sinker, and 2·45 metres of line — a considerable burden — was landed. The marks on the sinker indicated that the salmon had come from the region of Pillau in the Bay of Danzig. The following year a salmon measuring 102 centimetres in length and weighing 12·5 kilogrammes was landed in the Valkeakari fishing grounds off Kemi, and the marks on the sinker it carried indicated that it too came from the Bay of Danzig (from the region between Leba and Pillau).

Fig. 1 (on the left). Hook, sinker, and piece of line from the Pillau region in the Bay of Danzig obtained from a salmon caught near Seivästö in the eastern part of the Gulf of Finland in summer 1931. Slightly reduced in size.

Fig. 2 (on the right). Hook and sinker from the Bay of Danzig (between Leba and Pillau) obtained from a salmon caught on the Valkeakari fishing grounds off the mouth of the Kemi River in summer 1932. Slightly reduced in size.

When the International Council for the Exploration of the Sea was established at the beginning of the present century it initiated experimental research into the migration of salmon in the Baltic Sea. Silver tags inscribed with the initial letter of the State and a serial number were fastened to salmon — at first only adult salmon were marked which were available at hatcheries after the spawn had been obtained. The first results were poor, for many fish perished of weakness and others were caught on the first stages of their migration. Of 474 salmon marked in Finland between 1903 and 1916 only 25 were recovered, and

only three of them had moved farther than the mouth of the river where they were marked. One marked in the Oulu River was caught off Uusikaarlepyy (1910); one of those marked in the Kymi River (south Finland) was caught at Koivisto Island (1910), and a second fish from the Kymi River was caught off Memel in the southern Baltic (on 2. May 1907, weight 10 Kg.; marked in October 1905 and weighing 6·5 Kg.). The third case was one of the earliest proofs obtained that the second migration may also extend as far as the southern Baltic. The marking of adult salmon in Sweden during this period did not give any particularly noteworthy results.

The results of marking experiments in the southern Baltic excited greater interest. A Danish scientist, A. Otterstrøm, in the spring of 1906 marked 159 small salmon, mielnica, 42—52 cm. in length, in the Bornholm waters. During the summer of the same year 15, or about 10 %, were recovered in the same waters, but one of them travelled a long distance, arriving on 22. August at Oulu (Raatti). Thus it had travelled a distance of 1,350 Km. (the shortest route) in 4 months and 10 days, an average of 10 Km. daily. When caught it was a grilse weighing 1·7 Kg., which indicated that grilse also come from at nearest the southern Baltic to northern Finland.

The results of Henking's markings done in April 1919 on the Pomeranian coast at Gr. Horst are particularly noteworthy. He marked only 28 mielnicas whose weight varied from a half to one Kg. — those weighing a kilogramme may have perhaps already reached the grilse stage. Six of them were observed to have migrated long distances (Fig. 3.). As early as June 1920 two were caught in the northernmost part of the Bothnian Bay — one, weighing 5·5 Kg., on the Pensaskari fishing grounds off Kemi, and the other, weighing 6·5 Kg., the next day in the Korva Weir in the Kemi River. Apparently they had travelled the long distance together as far as the Pensaskari fishing grounds: the shortest route between Pensaskari and Korva Weir measures ca. 24 Km.

Further, in summer 1921, one of Henking's salmon, weighing 13·5 Kg., was caught in Luleå Archipelago in Sweden and another, weighing 11·5 Kg., at the mouth of Ångerman River, also in Sweden. As late as 1924 two more were caught, one — weighing 12 Kg. — in the Swedish archipelago of Tornio and the other in the Tornio River itself. From what we now know of the age and size of salmon, it is certain that these two salmon were on their second ascent when caught.

These results led to the opinion that the marking of smolts, i. e., salmon migrating for the first time, was particularly desirable despite the

(Fig. 3 — continued)

4. Marked as smolts at the mouth of the River Narva 1922—1941. Those recovered in the easternmost end of the Gulf of Finland weighed 400—700 g., those near Kotka 1.5 and 3.8 Kg., those from Raippaluoto (Gulf of Bothnia) 3.8 Kg., and the one caught off Lovisa under 1 Kg. and 41.5 cm. in length.

5. Marked at the age of two years in the Langinkoski Rapids in the Kymi River, in May 1932 (bred at Porla Hatchery). Caught 15. December 1937 in Poland off the mouth of the River Piasnica (to the west of Hela).

Fig. 3. Migration of Marked Salmon.

1. Marked when ca. 42 cm. in length in Bornholm waters 12. April 1906 and recovered 22. August 1906, length 49 cm. and weight 1.7 Kg.
2. Marked when 41—42 cm. in length on the coast of Pomerania near Gr. Horst in April 1919. Recovered 1920—1924, weighing 5.5—13 Kg.
3. Marked as two-year-old smolts and liberated in the Kokemäki River in May 1929. Recovered April and May 1930, weighing 665—800 g.

(continued on page 102.)

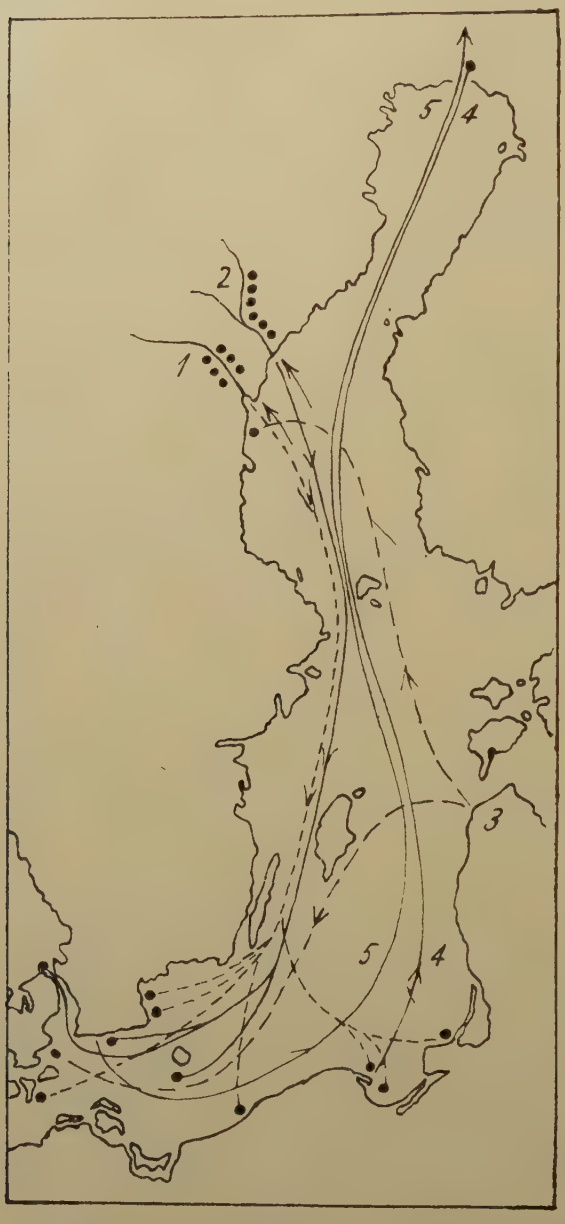


Fig. 4. Migration of Marked Salmon (mainly according to A l m).

1. Migration of smolts liberated in the Indal River in 1924—1926. The specimens caught at the western end of the southern Baltic weighed under 1 Kg. Those caught in Poland weighed 4.6 Kg. and 6.4 Kg., and those near Neukuhren 9.5 Kg. Six fish reascended the river.

2. Migration of smolts released in the River Ångerman in 1925—1926. The fish caught in Skåne weighed 0.5 Kg., that in Sjælland 0.85 Kg., and that near Bornholm 4 Kg. Six fish reascended the river.

3. Smolts marked at the mouth of the River Windau at the beginning of May 1930. The fish caught off Sundsvall on 24. August 1930 weighed 770 g., and the one caught near the Island of Amager in Denmark on 18. September 1931 weighed 4.85 Kg.

4. A specimen marked on 31. March 1933 near Hela in Poland when 40 cm. in length was landed in Kiviranta Weir in the Tornio River on 18. July 1933 weighing 1.5 Kg. and measuring 50 cm. in length.

5. A specimen marked in Skåne on 27. April 1932 when 46 cm. in length was caught at Kolari on 27. August 1933 weighing 7 Kg.

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(Fig. 5 — continued)

southern Baltic. Six of those marked in 1935 reascended the river in 1937, one weighing 6.9 Kg., two 9.0 Kg., two 9.5 Kg., and one 10.7 Kg.

3. Smolts marked in Poland in 1936—1938. One caught in Ångermanland on 20. September 1938 weighing 700 g., one in Kymi on 10. May 1939 weighing 900 g., one in Medelpad in March 1938 weighing 1.4 Kg., one in Korsnäs on the Finnish side of the Gulf of Bothnia weighing 1.4 Kg., and one in Vesternorrland (Örnskjöldsvik) on 4. July 1938 weighing 3.1 Kg. One was landed in southern Sweden near Karlshamn on 9. September 1938 measuring 55 cm.

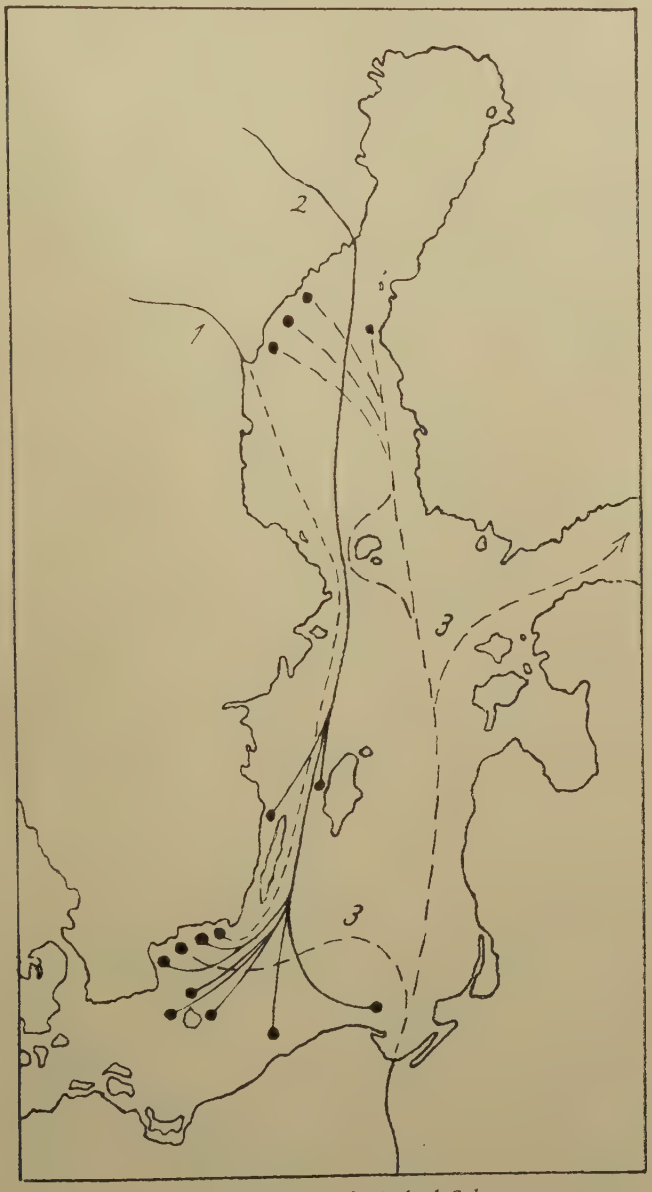


Fig. 5. Migration of Marked Salmon
(according to A l m, with certain changes and additions).
1. A female fish marked in the Indal River on 26. October 1937, when 82 cm. in length and 4.1 Kg. in weight, was landed on its second migration on 24. January 1938 weighing 6.6 Kg. and measuring 93 cm. in length.
2. Marked salmon of varying size starting on their second migration from the River Umeå in the autumns of 1935 and 1936. Caught again in 1937 and 1938 in the
(continued on page 104.)

difficulties involved. In Sweden this operation has been performed by Gunnar Alm, now administrative chief of the Freshwater Department of the Fisheries Board. In 1924—1926 he had more than 6,000 smolts from fish hatcheries marked; some were liberated in Ångerman River and the rest in Indal River. The results were as follows (Fig. 4). About a year later five specimens were found in the southern Baltic, two on the coasts of Skåne, two on the coasts of the Danish islands, and one on the coast of Pomerania. They were mielnicas below 50 cm. in length. Later in the summer three specimens at the grilse stage were caught in the Indal River and one in the Ångerman River. From two to two-and-a-half years after marking eight of them were caught at the small salmon stage, weighing from 4 to 6 Kg., of which two were on their ascent of the Indal River and two of the Ångerman River; the remaining four were caught in the southern areas of the Baltic, one near Hela, one in Danzig Bay, one in Bornholm waters, and one in Skåne. After an absence of about three years four more were caught, one in the Indal River and three in the Ångerman River. Thus the migrations of twenty-one of the salmon were determined; twelve of them had returned to the river where they were liberated after marking.

After nine years suspension, the marking of salmon was resumed in 1935, with slight alteration in method. The results obtained from these experiments were considerably more abundant than from the earlier ones. Chiefly older salmon from which spawn had been taken in hatcheries were marked. During the interval some marking had been performed at Älvkarleö Station at the mouth of the Dal River. One specimen marked there in 1928, measuring 91 cm. and weighing 7 Kg., was recovered in the same river two years later, weighing 14·1 Kg. and measuring 113 cm.

Of the salmon, 60 to 73 cm. in length, which were marked in the Indal River in November 1935, two were caught during the following spring and summer in the sea off Sundsvall, and three were recovered after their reascent into the Indal River. Of the salmon marked in autumn 1935 in the Umeå River (Fig. 5) four were caught about a year later in Bornholm waters. Two of them were caught on the same day, 14. December 1936, and almost in the same place, near Hasle. One of these fellow-travellers, which bring to mind Henking's two salmon mentioned above which arrived at Kemi in 1920, was a female weighing 6·1 Kg. and measuring 96 cm. when marked, while the other was a male 63 cm. in length and 1·8 Kg. in weight when marked. When recovered

(Fig. 6 — continued)

2. Smolts marked in Poland in October 1937—1938. One caught in the north on 24. April 1939 weighed 1.15 Kg., and another on 14. September 1939 weighed 350 g. Those landed in southern Sweden weighed 1.1 Kg. and 1.04 Kg., and the one landed at the southern end of Öland was 30 cm. in length.

3. Two caught in central Sweden were 90 and 95.3 cm. long and weighed 5.2 Kg. and 8.5 Kg. repectively. They were caught on successive days, one further north on 13. June and the other on 14. July 1939. Both had been marked in Poland in October 1936.

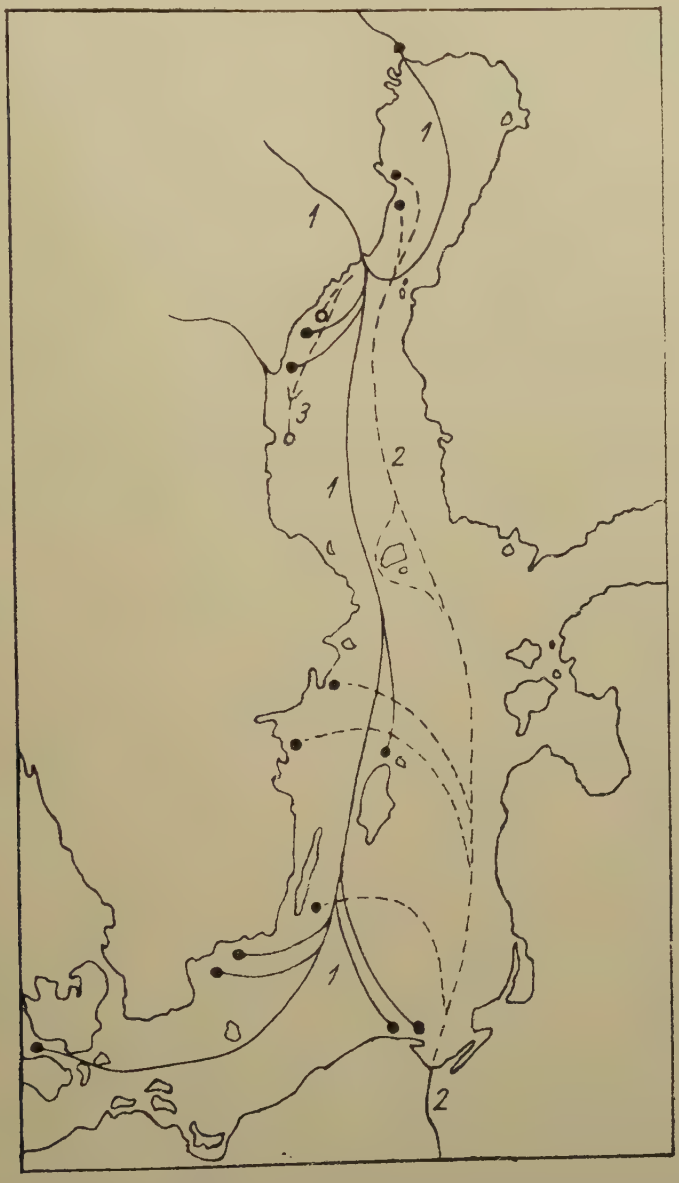


Fig. 6. Migration of Marked Salmon (according to A l m, with some changes). 1. Specimens marked in the River Umeå in the autumns of 1937 and 1939 on their second migration. Of the former, one specimen which was 76 cm. in length and 3.2 Kg. in weight when marked was caught on 5. July 1939 in the Edefors rapids in the River Lule, weighing 8.3 Kg.; the remainder were caught in January—June 1939. One specimen marked in autumn 1939 was caught on 16. August 1940 in Vesternorrland (Örnskjöldsvik) weighing 10.7 Kg., compared with 6.5 Kg. when marked.

(continued on page 106.)

the former was 2 cm. longer but of the same weight, while the latter had grown 17 cm. and put on 4·6 Kg. in weight. Further, three specimens were recovered in April and May 1937 in other parts of the southern Baltic, namely, Kalmar Sound, and near Hela and Leba. It is of particular interest that six of them were recaught in the summer of 1937 in the River Umeå. These, 90—110 cm. in length when marked, had not grown in length during their second migration but had put on 1·9—2·7 Kg. in weight.

Of salmon marked in the River Umeå in 1936, one was caught in Danish waters (Hammeren, December 1937), one in Blekinge (April 1938), and one in Gotland waters (May 1938).

Of the salmon marked in the River Umeå in 1937 six specimens in all (Fig. 6) were caught in winter and spring 1939 in southern parts of the Baltic, two in Blekinge, two near Hela in Poland, one in Denmark (near Odense), and one in Gotland. Furthermore, two salmon were caught in summer 1939 — obviously they had returned to the Bothnian Bay — one on the coast of Vesternorrland (Grundsunda) and one in the Edefors rapids in the River Lule. It is noteworthy that this salmon had made its second ascent in a *different* river from its first ascent.

Of the salmon marked in October 1939 also in the River Umeå one, which was 95 cm. in length and 6·5 Kg. in weight at the time of marking, was recovered in August 1940 near Malmö, weighing 10·7 Kg. and measuring 100 cm. in length.

At the end of June and in July 1939 the Swedes marked in the archipelago of the River Lule a number of mielnica, 40—57 cm. in length, and some grilse (Fig. 7). Three were caught 4 to 10 days later in the Pite, Kalix, and Tornio Rivers, a fourth was caught twenty-two days later off Oulu, and a fifth, twenty-seven days later in the Lule River. One had migrated as far as Latvija and was caught 7 Km. from the mouth of the River Duna a year and a half later.

The Poles also marked young salmon prior to the second World War. Eleven smolts marked by them were caught on the Swedish coasts of the Gulf of Bothnia, between the southern end of Öland and the Skellefte River, and three were caught in Finnish waters. I shall refer to these cases (Fig. 5), except for one which follows, in another connexion. On 18. July 1933 a grilse weighing 1 Kg. and marked in Poland on 31. March 1935 was caught in Kiviranta Weir in the Tornio River. Thus this specimen had travelled from the southern coast of the Baltic to the northern end of the Gulf of Bothnia in 109 days — the shortest route measures 1,365 Km. When measured after capture, it was 40 cm. long and weighed 350—400 g. Another interesting specimen was caught the same summer on 27. August in the Tornio River; it had ascended as far as Kolari and weighed 7 Kg. It had been marked on 27. April 1932 — a year and a quarter earlier — in Skåne near Lilla Bedinge, when it measured 46 cm. in length and weighed about half a kilogramme.

Markings have not been performed in Finland since 1935, because the 1915—1935 markings gave relatively scanty results. The first result

to be mentioned dates from 1934. A salmon, nearly 60 cm. in length and 2·6 Kg. in weight, was caught off Reposaari Island in May. This fish had been marked and liberated in the Kokemäki River in the preceding year, and was apparently making for the same river when caught.

Other, more interesting cases relate to 1930 (Fig. 3). Three specimens marked at the Porla Hatchery as two-year-old smolt and liberated in the Kokemäki River in the spring of 1929 were caught in May 1930, weighing 660—800 g., one in Himanka parish, a second in Kalajoki parish in the Bothnian Bay, and a third in the waters off Tiurinsaari Island of Koivisto in the easternmost part of the Gulf of Finland. Thus, the first two travelled north from the mouth of the Kokemäki River, while the third took a surprising direction and arrived, as mentioned, far to the east. In the summer of the same year (1930) one specimen of about the same size marked in Latvija in the early spring was landed in Sundsvall in Sweden. These four cases led me to call attention, at a meeting of the Salmon and Trout Committee of the International Council held in Gdynia in 1934, to the probable influence of currents on the main routes followed by migrating salmon. On the assumption that the salmon, travelling in shoals, hunt their food among the shoals of fish living in the open sea, they must consequently follow the direction of the currents in the upper layer to a considerable extent. Thus the resultant water movements of the Baltic determine the main direction of migration (Fig. 8). As a result of the rotation of the earth the general circulation in the Baltic Sea and the Gulf of Bothnia is

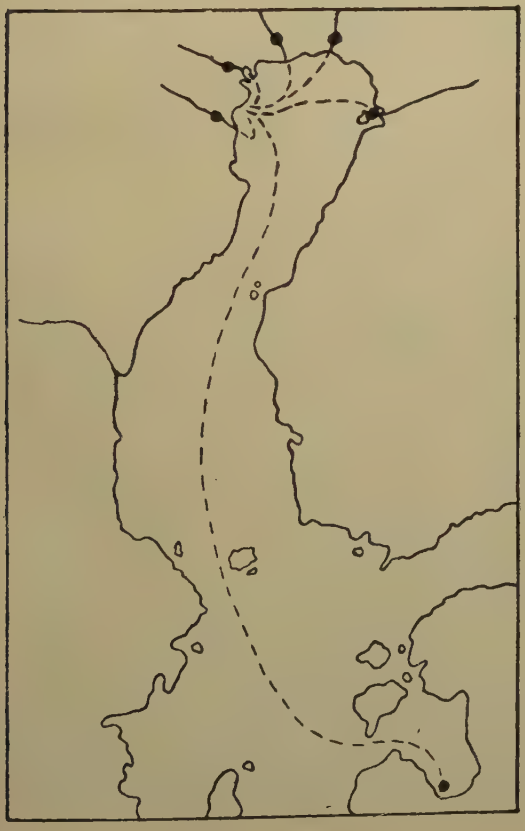

Fig. 7. Migration of Marked Salmon (according to A l m, with certain changes). Salmon measuring 40—57 cm. in length marked in July 1939 in the archipelagos of Piteå and Luleå. Three ascended nearby rivers 4 to 10 days later, one appeared off Oulu after twenty-two days, one ascended the River Lule twenty-seven days later, and one appeared in the Bay of Riga one year and two months later.

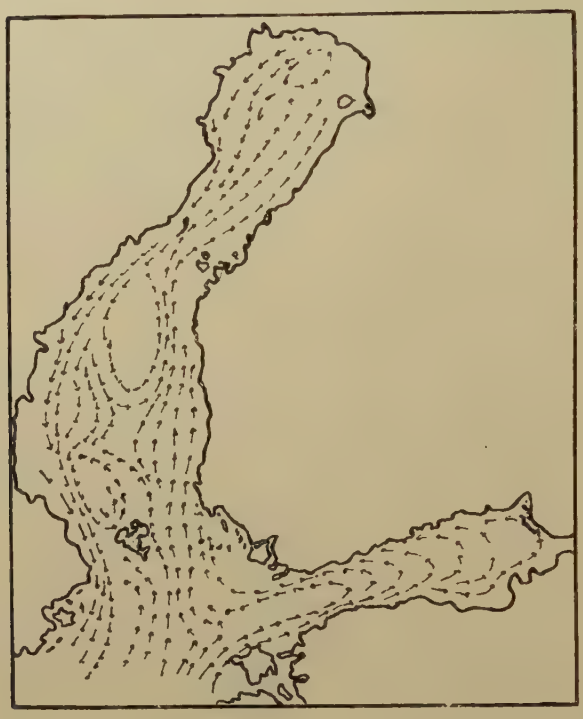

Fig. 8. The Water movements (in Summer) of the Upper Layers in the Northern Baltic (Gulf of Bothnia and Gulf of Finland); after W i t t i n g.

such that the currents trend to the north on the eastern side, and to the south on the western side. In view of this the results obtained in 1930 from markings in Finland and Latvija would not represent exceptional but normal conditions. And since the resultant current in the Gulf of Finland runs eastward on the southern coast and westward on the northern coast, we can to a certain extent account for the migration of the salmon mentioned above from the mouth of the Kokemäki River to the waters of Tiurinsaari Island of Koivisto.

Results obtained later support this conception. In 1932 Estonian fishery experts (E d w a r d R e i n w a l d t) began to mark young salmon at the mouth of the Narva River. Five of them were caught on the northern coast of the Gulf of Finland (Fig. 9), two of them in the remotest corner of the Gulf at Tyrisevä and Vitikkala of Uusikirkko, two in the Kotka-Hamina Archipelago, and one off Lovisa. It is perhaps noteworthy that they were recovered a relatively long time after marking — the first (at Tyrisevä) about a year and one-and-a-half months, the second (at Uusikirkko) a year and four-and-a-half months after marking, while in the Kotka-Hamina Archipelago one was caught a year and eight months, and the other, two years and seven-and-a-half months after marking; we have no information about the date of marking of the small salmon — 41·5 cm. in length — caught off Lovisa in 1938.

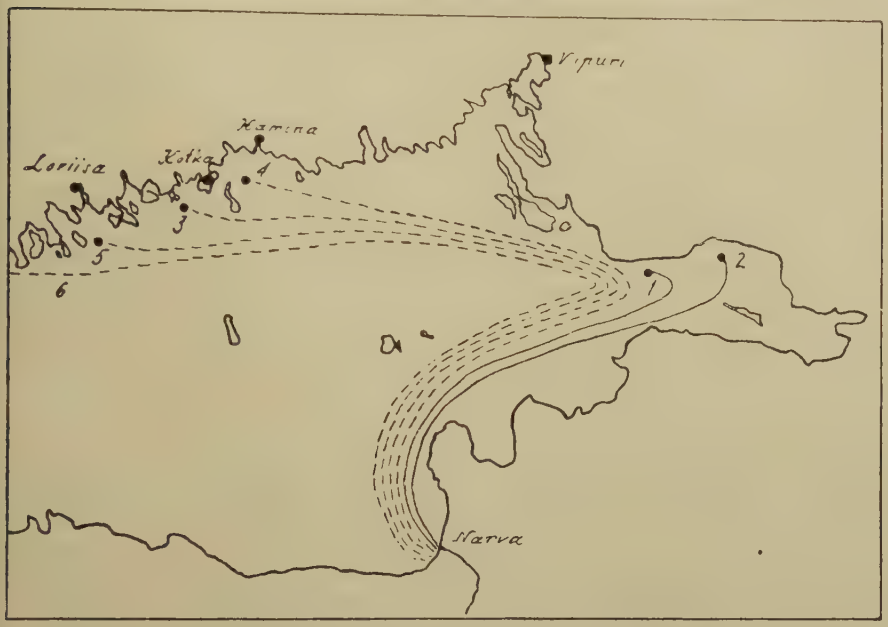


Fig. 9. Migration of Marked Salmon.
1. Caught 4. March 1935 weighing 700 g., marked 19. October 1933.
2. Caught 28. December 1935 weighing 440 g., marked 1. November 1934.
3. Caught at the beginning of June 1936 weighing 1.5 Kg., marked 1. November 1934.
4. Caught 11. June 1937 weighing 3.8 Kg., marked 26. October 1934.
5. Caught 7. May 1938, 41.5 cm. in length.
6. Caught 7. June 1943 weighing 3.2 Kg. at South Wallgrund in Replot (Gulf of Bothnia).

One of the salmon marked on the Narva River had also made a surprising journey; it was caught, weighing 3·2 Kg., in summer 1943 at Replot in the Gulf of Bothnia (Kvarken). The date of marking is unknown, but it might be 1941. This case is, in a way, the opposite of that in which a salmon marked as a smolt in Kokemäki River in 1929 was caught at Koivisto in 1930.

My conception of the influence of the resultant water movements on the migration of salmon in the Baltic Sea is also supported by the migrations of the majority of the smolts marked in Poland (Fig. 5). Two small salmon marked as smolts in Poland, in addition to the one that reached the Kiviranta Weir in the Tornio River, have been caught in Finland, both in May 1939, one, weighing 900 g., in the Gulf of Finland off the mouth of the Kymi River, and the other, weighing 1·4 Kg., in the Gulf of Bothnia in the vicinity of Korsnäs. Correspondingly, specimens have been caught on the Swedish coast in the central regions of the Gulf of Bothnia; a salmon weighing 700 g. (20. September 1938) was taken in Ångermanland, another of 1·4 Kg. in Medelpad (March 1938), and yet another of 3·1 Kg. in Vesternorrland (4. July 1938). One of the smolts

marked at the same time was landed, measuring 55 cm., in southern Sweden (near Karlshamn) on 9. September 1939.

The specimens marked in Poland and recovered in Sweden in 1939 require more explanation (Fig. 6). The two fish caught on the coast of northern Sweden on 24. April — one weighing 1·15 Kg. — are clear cases; they had obviously travelled directly northwards. But the migrations of the two specimens caught on the western coast of the Baltic — weighing 1·1 and 1·4 Kg. — and the one caught on the southern point of Öland — measuring 30 cm. — are more difficult to explain. Furthermore, there is the special case of the two salmon which were caught on successive days, 13. and 14. June 1939 in central Sweden, in the Bays of Örnskjölsvik and Ärnövik. They were of the same size, 90 and 90·5 cm., but differed in weight, 5·2 and 8·5 Kg. Thus they were older fish whose travels in the sea had already lasted two years. Since the first was caught in the northern bay and the second in the southern bay, it seems highly probable that they had travelled together, like the two couples mentioned above. On this assumption it may be concluded that they had travelled from the north to the south, which is the route quite commonly followed by the salmon migrating from the rivers of northern Sweden.

I wish to call attention to another aspect. The great majority of the marked salmon have been retrieved in the sea. In the foregoing survey, only 24 cases of specimens recovered in rivers or off the mouths of rivers are recorded. In thirteen of them the first ascent was in progress, and in eleven, the second ascent. In all the former cases the salmon have returned to their original rivers, likewise in the latter, with the exception of one which was marked in the Umeå River but was recovered in the Lule River at Edefors. Thus with respect to the Baltic Sea too we note the phenomenon — so difficult for man to account for — that salmon return to spawn in the rivers of their origin, or in the case of hatchery specimens, to the rivers whence they migrated. Doubtless we may assert with reference to the one exception that it confirms the rule.

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# Reviews.

**E. F. Armstrong** and **L. M. Miall.** "Raw Materials from the Sea." pp. XI and 164: 21 plates. Constructive Publications Limited, Leicester, 1943.

This is primarily a book for the general reader interested in the methods and economic possibilities of extracting materials from lakes and the sea. A good account is given of the history, economics, and modes of extraction of common salt, bromine, and magnesium from sea water. The modern techniques are clearly described and in more detail than has hitherto appeared in the general literature. The account of the D o w process for the extraction of magnesium is particularly good.

In the chapter on potassium the activities of Palestine Potash Ltd. are fully described, and some attention is given to the American work. A chapter on products from sea-weed is devoted particularly to the extraction of iodine, little attention being given to the organic materials now being manufactured in considerable quantities. A discussion of the production of potable water from salt water is included. References are given to the more important of the modern publications on commercial processes and their economics.

Preceding these chapters on industrial work are three dealing with the physics, chemistry, geochemistry, and biology of the ocean. In such a small space the treatment is necessarily very superficial and indeed a number of erroneous statements are found in this section.

*H. B.*

**N. W. Rakestraw** and **T. von Brand.** "Decomposition and regeneration of nitrogenous organic matter in sea water." Biol. Bull. **72**, No. 2, pp. 165—175. Cambridge & Woods Hole, Mass., 1937.

**T. von Brand, N. W. Rakestraw** and **C. E. Renn.** "Further experiments on the decomposition and regeneration of nitrogenous organic matter in sea water." Biol. Bull. **77**, No. 2, pp. 285—296. Cambridge & Woods Hole, Mass., 1939.

**T. von Brand** and **N. W. Rakestraw.** "Decomposition and regeneration of nitrogenous organic matter in sea water. III. Influence of temperature and source and condition of water." Biol. Bull. **79**, No. 2, pp. 231—236. Cambridge & Woods Hole, Mass., 1940.

T. von Brand and N. W. Rakestraw. "Decomposition and regeneration of nitrogenous organic matter in sea water. IV. Inter-relationship of various stages; influence of concentration and nature of particulate matter." Biol. Bull. **81**, No. 1, pp. 63—69. Cambridge & Woods Hole, Mass., 1941.

T. von Brand, N. W. Rakestraw and J. W. Zabor. "Decomposition and regeneration of nitrogenous organic matter in sea water. V. Factors influencing the length of the cycle; observations upon the gaseous and dissolved organic nitrogen." Biol. Bull. **83**, No. 2, pp. 273—282. Cambridge & Woods Hole, Mass., 1942.

N. W. Rakestraw and T. von Brand. "Decomposition and regeneration of nitrogenous organic matter in sea water. VI. The effect of enzyme poisons." Biol. Bull. **92**, No. 2, pp. 110—114. Cambridge & Woods Hole, Mass., 1947.

This series of papers constitutes an important contribution to our knowledge of the mode of decomposition of plankton material under experimental conditions. Since the fertility of the sea is dependent upon the cycle by which inorganic nitrogenous compounds are regenerated, the results are of widespread importance.

The experimental procedure was similar throughout the work and, in general, consisted in allowing various kinds of planktonic and other material to decompose in carboys of sea water kept in the dark; samples of the cultures were withdrawn at intervals and by analysis, the changes in the ammoniacal, nitrite, and nitrate nitrogen fractions have been followed during decomposition processes. The variables whose action has been considered are clearly indicated by the titles of the individual papers given above.

Throughout the series a similar decomposition sequence was observed, namely, particulate matter gave rise to ammonia which was oxidized to nitrite, the latter being in turn oxidized to nitrate. Although the length of any stage varied from one series of experiments to another (the total duration of the nitrite stage being particularly irregular) the sequence of events was always similar. The rate of decomposition was greatest in the first few days, with the production of ammonia; ultimately the rate of formation of ammonia slowed down and eventually ceased. During this period neither nitrite nor nitrate were formed. Although not conclusively demonstrated, the chemical evidence suggests that soluble organic nitrogenous compounds do not play an important part as precursors of ammonia. However, when a second cycle was carried out in the same culture, by further addition of decomposable material, there was a lag in the appearance of ammonia in comparison with the disappearance of particulate nitrogen, suggesting that under these circumstances the formation of intermediate nitrogenous compounds of high molecular weight may take place.

Concurrently with the production of ammonia there was a rapid development of the bacterial flora, and it is therefore suggested that autolytic decomposition plays a comparatively small part. It should be noted, however, that the absolute numbers of bacteria were never high; indeed, little larger numbers were obtained than are present in stored, unfiltered sea water without added material. Nitrate appeared only when nitrite disappeared, which never seemed to happen as long as a significant quantity of ammonia remained. Under anaerobic conditions a little ammonia may be formed, but a strong odour of hydrogen sulphide was observed and no nitrite appeared.

The behaviour of ammonia, nitrite, and nitrate in these experiments is similar to that obtained by other workers using pure bacterial cultures and the appropriate substrate. The slowest of these three stages is the oxidation of nitrite to nitrate, an efficient population of the specialized *Nitrobacter* flora apparently developing at a slower rate. When decomposition had stopped there was 20—35 % residual nitrogen (calculated on organic plankton basis) and this was presumably present either as non-decomposable residues, bacterial cells, or other forms.

The concentration of particulate matter had little effect on the rate of the processes, but the source of material had some effect. The rate of decomposition was most rapid with mixed plankton, slower with pure diatoms (from cultures) and slowest with yeast cells. A ciliate behaved similarly in harbour water to the diatoms but did not proceed to nitrate in deep sea water.

The course which the decomposition takes when new organic matter is added depends on the bacterial flora which then predominates. There was no evidence of the inhibition of the formation of nitrite or nitrate by ammonia and in general a shortening of the cycle takes place, so that, for example, ammonia and nitrite appear only in small quantities if new organic matter is added after the development of a vigorous nitrate flora. Low temperature may completely inhibit part of the processes; nitrite formation may be completely inhibited or only retarded depending upon the particular organisms present, whilst oxidation of nitrite to nitrate was less inhibited than the nitrite-ammonia conversion.

This nitrogen cycle can be repeated; exposure to light at the nitrate stage and inoculation with living diatoms resulted in a rapid growth of the latter with a consequent depletion of the nitrate. Three successive cycles were in this way carried through and since each addition of new organic matter resulted in an undecomposable residue, the total level of refractory residual nitrogen gradually rose with each successive cycle. Further, inoculation and exposure to light either at the ammonia maximum or prior to the nitrate stage lead both to a depletion of the inorganic nitrogen present and to a vigorous growth of diatoms, indicating that at these stages no toxic compounds had been formed which would inhibit the development of phytoplankton.

The source of the water had an important influence on the decomposition. The behaviour with water from the oxygen minimum layer (800 metres) and from the surface of a deep sea station was similar to that of the inshore water already described, but with deep water (1200 metres) from this station decomposition did not proceed further than the formation of ammonia. Further, none of the samples showed any difference between sterilized (by filtration) and untreated sub-samples, suggesting that the necessary bacterial inoculum was carried by the diatoms. It therefore follows either that the deep water contains a factor inhibiting the production of an oxidizing bacterial flora, or that it lacks an essential factor necessary for its development. That it was lack of an essential constituent, rather than the presence of an inhibiting factor, is indicated by the fact that evaporation and ignition of harbour water prior to addition of particulate matter resulted in a retardation in the formation of ammonia, whilst production of nitrite was even more retarded and there was a complete absence of nitrate formation. However, boiled diatoms showed little difference from living material when introduced into either untreated or sterilized sea water, and the maintenance of aseptic conditions is called into question by the authors. The evidence

suggests that it is easier to eliminate the organisms responsible for oxidation than those for ammonia formation. However, on one occasion the decomposition of diatoms proceeded normally, nitrate being ultimately produced in deep water cultures.

In their most recent paper (Part VI) in taking up these studies again, the effect of a number of enzyme poisons on various stages of the cycle have been investigated. The production of ammonia by micro-organisms may take place by hydrolytic, reductive, and oxidative deamination depending both on the conditions and on the micro-organisms present. That KCN retards the production of ammonia in these decomposition cultures, but does not completely suppress it, suggests that oxidative deamination (known to be completely inhibited by KCN in all examples studied) is the most important route to the liberation of ammonia; that some ammonia production still takes place, even in the presence of cyanide may be due either to a weakly developed mechanism by the same bacteria, or to the slow production of a different bacterial flora liberating ammonia by an alternative method. Nitrifiers are more sensitive and were destroyed by the usual well-known poisons used. Cyanides, carbamates, iodates, and fluorides interfere with nitrite and nitrate formation, suggesting that dehydrogenases are involved in their formation. The possible uses of KCN as a preservative for samples prior to analysis for nitrite and nitrate are clearly indicated.

Several of these decomposition cultures showed an unexplained increase in the total nitrogen during the experiments, i.e., more was generated in the soluble form than disappeared from the planktonic material. Four possible causes were examined:—

1. Participation of other forms of nitrogen, particularly dissolved organic nitrogen.
2. Sampling errors.
3. Nitrogen fixation.
4. Contamination.

The tracing of this increase is a matter of very considerable technical difficulty, but the evidence obtained was largely in favour of contamination from air during the experimental period.

These authors have covered the influence of a large number of variables, each of which raises its own particular new problems. An intensive study of the mechanism by which any of these affects the processes concerned is now required, when it should be possible to relate more closely the results of these and other culture experiments to the changes taking place in the sea.

*H. Barnes.*

**K. F. Wiborg.** "The Production of Zooplankton in the Oslo Fjord in 1933—1934, with special reference to the Copepods." Hvalrådets Skr., No. 21, pp. 87, 5 figs. Oslo, 1940.

The collections on which this intensive study of the zooplankton of the Oslo fjord was based were made in conjunction with hydrographic and phytoplankton investigations from June 1933 to May 1934. A few supplemental hauls were made in 1938. The material was collected by vertical hauls, most of them in two steps, from the bottom, thus ensuring that the whole depth was sampled. Of these collections the copepoda formed the

greater part, numerically never less than 56 % and sometimes reaching 96 %, and consequently most of the paper is devoted to their consideration.

The general configuration of the Oslo fjord, 100 kilometres long, includes the usual feature of a sill or threshold at the entrance, cutting off the outer waters of 35 ‰ salinity and over and rising to a depth of 110 m. from the surface, with deeper basins, down to 160 m., in the course of the fjord. A much shallower sill at Drøbak with a depth of 40 m., supplemented by an artificial causeway closing half the channel, divides the fjord into an outer and an inner basin.

The hydrographic conditions in the fjord, a variable surface layer of low salinity overlying water of more uniform salinity of 33—34 ‰ in the deeper basins, are considered in relation to the various species of the zooplankton occurring in the collections. Almost every species met with appears to be a normal inhabitant of the fjord, reproducing itself there and not necessarily relying on additions to the stock from deep water outside, though the author is inclined to the view that renewals from the outside are of considerable importance. Even such normally Atlantic species as *Calanus hyperboreus, Chiridius armatus, Euchaeta norvegica,* and *Oithona spinirostris* (to use the names applied in the paper) find there conditions favourable for existence and even make their way into the inner fjord above Drøbak. Purely neritic species such as *Pseudocalanus minutus, Centropages hamatus,* and *Temora longicornis* occur throughout the fjord. Only *Oithona nana* and, curiously enough, *Metridia longa,* of the copepods, seem to find the outer fjord relatively unfavourable.

As the hauls were always made in daylight it was not possible to say which species, by coming to the surface by night, would be most liable to be transported by wind-induced surface currents, which seem to be the main cause of mixing of the surface layers of the various basins. Data as to the speed of these currents and of the sub-surface compensation currents might throw some light on the relative parts played by local reproduction and immigration in maintaining the stocks of the various species.

In a convenient summary the author has indicated briefly his views of the status of each of the species mentioned in the paper, but in order to get full values from the mass of details provided, the whole paper should be read in conjunction with that by Braarud and Ruud on the hydrographic conditions (Hvalrådets Skr., No. 15).

*G. P. F.†*

**G. A. Riley** and **D. F. Bumpus.** Phytoplankton—Zooplankton Relationships on Georges Bank." Journ. Mar. Res., Vol. **6**, No. 1, pp. 33—47, figs. 11—12, New Haven, Conn., 1946.

**G. A. Riley.** "Factors controlling Phytoplankton Populations on Georges Bank." *Ibid.*, pp. 54—73, figs. 14—21.

**G. A. Riley.** "A Theoretical Analysis of the Zooplankton Population of Georges Bank." *Ibid.*, Vol. **6**, No. 2, pp. 104—113, figs. 27—31. New Haven, Conn., 1947.

**G. A. Riley.** "Seasonal Fluctuations of the Phytoplankton Population in New England Coastal Waters." *Ibid.*, pp. 114—125, figs. 32—34.

L'auteur a nettement donné la raison et la portée des développements mathématiques qu'il introduit dans l'étude des facteurs contrôlant le développement du phytoplancton. Il montre en effet que la méthode statistique

provenant de l'observation directe peut être complétée par une étude théorique qui, en s'appuyant sur elle, en généralise les résultats. Sans doute, dans le calcul doivent être introduites certaines hypothèses de base, dont l'auteur lui-même ne semble pas entièrement satisfait. Aussi bien, ce qu'il se propose est non pas d'arriver à des résultats d'une exactitude rigoureuse "but rather to describe promising techniques that warrant further study and development". Sous ces réserves, les tentatives de G o r d o n A. R i l e y sont extrêmement intéressantes.

Ayant constaté que dans les eaux du Georges Bank la quantité de phytoplancton est inversement proportionnelle à celle du zooplancton, au moins quand celui-ci atteint son maximum, et voyant la raison de ce phénomène dans la quantité de plantes microscopiques que prélèvent les herbivores pour leur nourriture, il essaie de calculer théoriquement l'importance de ce prélèvement, ce qui donne 25 $^0/_0$ du poids animal par jour en Avril et 17 $^0/_0$ en Mai.

Les variations de la population du phytoplankton, son cycle saisonnier sont également étudiés en fonction des différents facteurs du milieu. Comme les plus importants il faut retenir, parmi ces derniers, la radiation solaire, la température, la transparence, et la teneur en phosphates de l'eau, l'épaisseur de la couche isotherme de surface, l'abondance du zooplancton. Les variations observées de ces facteurs, combinées avec les données expérimentales, permettent de poser une équation qui exprime les variations saisonnières du phytoplancton, et d'en tracer une courbe dont l'exactitude se révèle du même ordre que celle fournie par les données statistiques.

De même, l'expérimentation et les statistiques fournissent les valeurs numériques d'une équation qui permet de calculer les variations du cycle saisonnier des organismes planctoniques herbivores en fonction de leur nutrition, de leur respiration, de leur disparition du fait de prédateurs ou de mort naturelle. Mais tant d'imprécisions demeurent encore dans l'évaluation de chacun de ces facteurs que les résultats en restent quelque peu spéculatifs. Cependant le parallélisme approché des courbes obtenues par le calcul et l'observation montre que la voie est bonne et demande seulement d'être approfondie.

Après avoir ainsi étudié le plancton du Georges Bank, l'auteur a appliqué avec succès les mêmes méthodes à l'étude du phytoplancton de la région de Woods Hole. Entre les deux régions existent à ce point de vue des différences notables qui se traduisent sur les courbes et qui sont dues aux différences du milieu: eaux du large d'une part, eaux côtières de l'autre.

Les biologistes auront profit à lire les travaux de l'auteur, qui leur ouvriront des horizons nouveaux.

*Louis Fage.*

# Current Bibliography.

Prepared by the Editor.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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